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Metal Progress

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E. Engin

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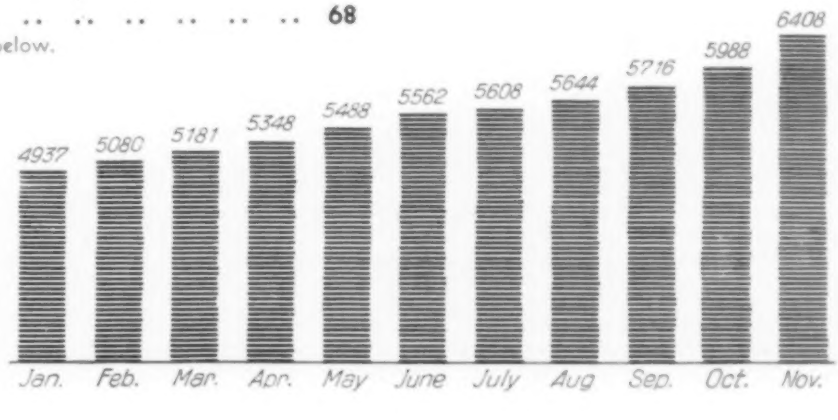
Ernest E. Thum, Editor

Observe the piles of magazines (net paid circulation of Metal Progress) growing month by month throughout 1934! Membership in the Society actually started on the uninterrupted up-grade in June of 1933 . . . . . Advertising revenue was also better in 1934 than in 1933, month by month except once, and one month gave the largest gross in history (the big October issue).



NON-FERROUS METALS

today and tomorrow

By Zay Jeffries
Consulting Metallurgist
Aluminum Co. of America
Cleveland

AS WE LOOK for the reasons for the great variety and diversity of the metal industry, they are not difficult to find. Each metal has gained its commercial status because it meets certain requirements more economically than any other material, or because its use provides some special satisfaction to human beings. Tungsten for lamp filaments and steel for rails, for example, meet their respective requirements with greater economy than any other known materials, and since economy is the main factor in these uses, these materials have no competition. Merely because a metal is high priced is no bar against its use for economy reasons. Platinum and gold used in industry and in the laboratory provide certain services more economically than any other materials; their use in jewelry, on the other hand, may depend on the degree of satisfaction afforded human beings. The consumption of large tonnages of metal, however, is based primarily on *economics*.

A great variety of properties and many combinations of properties are now available to the engineer. It might seem to the layman as if too many metals and alloys were already available, but the engineer is ever asking for properties and combinations of properties not yet obtainable.

The pure metals possess a great range in properties, but our civilization would indeed be backward if it were not for the new and wonderful combinations of properties obtainable in alloys. No pure metal, for example, is capable of being permanently magnetized; the permanent magnet and all that it has done for the electrical industry can be credited to the art of alloying.

At one time the metal industry was rather simple. The metal producer offered his product for sale, and the uses depended upon a few fundamental properties such as plasticity, hardness, and durability. Gradually the industry has become more and more complex until at the present time the metal supplier must know something about almost every industry. For this reason it may be interesting to consider some of the properties which are at present appraised in the selection of one or two metals for various uses.

Portions of an address presented before a meeting at last National Metal Congress, designed to interest members of the Metropolitan Section, American Society of Mechanical Engineers

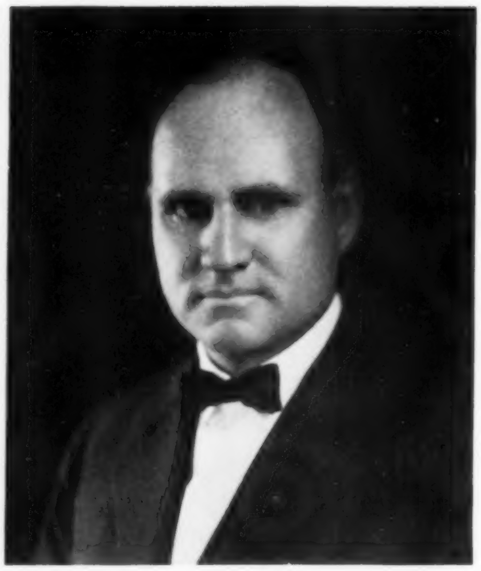
Wire for heating elements in electric heating devices must, of course, be plastic in order to be got into

the wire form; it must have a relatively high melting point and be resistant to oxidation in the air at a high temperature. It must not otherwise deteriorate as a result of high temperature, and it should have a relatively high electrical resistivity. Appraisal of such wire requires tests unknown to the ancient metal users.

In a similar way other metal is tested for its resistance to many kinds of corrosion; its ability to withstand high temperatures and low temperatures; its ability to withstand changes in temperature; its electrical resistivity; its coefficient of expansion; its change of these properties with change in temperature; its ability to be formed by pressing or other means; its ability to receive coats of enamel or paint or other surfacing such as electroplated and "hot dip" coatings; its reaction to certain chemicals and its behavior toward ink, as, for example, in the lithograph industry; the nature of the surface with reference to heat radiation; its light reflectivity.

The behavior of its surface in certain solutions for use as electrolytic condenser metal and for dry condensers must be known. Color and maintenance of color, machinability, electron emission, sensitivity to light for photo-electric cell purposes, behavior in an electric arc, magnetic characteristics, bearing qualities, resistance to impact with both heavy and light blows, resistance to repeated stresses, in addition to the usual properties of tensile strength, yield strength, hardness, per cent elongation, and density, must be determined from time to time.

Other qualities are important in determining metal utility. Consider copper, for instance, in its large use in the electrical industry. Among the properties desired for this purpose are ease of fabrication in both wrought and cast shapes, high electrical conductivity, good corrosion resistance, ease of soldering, weldability, machinability, toughness, plasticity, relatively high melting point, retention of plasticity at subnormal temperatures, ease of varying tensile strength and hardness by cold working, ability to withstand shock and repeated stresses, favorable behavior in an arc and high electrical conductivity. First cost and high salvage value also are of importance.



Zay Jeffries

Past President of American Society for Metals — Only One of the Honors Won by This Peer of American Metallurgists. Photo by Blank & Stoller

Internal combustion engine pistons require a totally different combination of properties. The piston should be light to reduce inertia forces; it should be hard, strong, and resistant to repeated stresses both impact and ordinary; it should be a good bearing material both against the cast iron of the cylinder wall and piston rings and the steel of the wrist pin; it should be strong at elevated temperatures, have high heat conductivity, and be able to withstand many heatings and coolings without substantial deterioration. It should have toughness at ordinary, elevated, and subnormal temperatures. It should have a low coefficient of thermal expansion and be relatively free from the potentiality of permanent change in volume in the motor. The alloy should be readily castable and machinable, and when put into the motor, internal stresses should not be excessive, and it should have a surface which holds a thin film of lubricant tenaciously. In addition to all of the above, resistance to a variety of corrosive influences, both during storage and use, is desired. Only two materials, aluminum alloys and cast iron, meet these requirements commercially. No matter which is selected, some compromise is necessary. Iron has the lower cost and lower coefficient of expansion, while aluminum alloy has higher heat conductivity and lower weight.

We will content ourselves with just one other which illustrates the way the metallurgist has delicately adjusted metallic properties for use in modern metallic products.

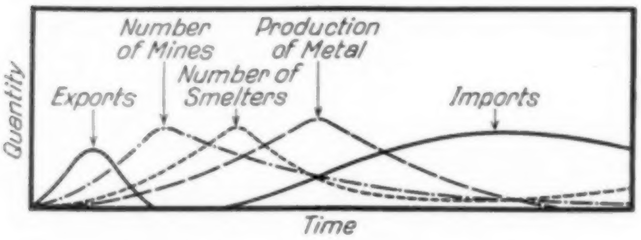
Various forms of vacuum tubes comprise an important group of commercial products. They include among others the radio and X-ray tubes. To try to enumerate, for example, all of the requirements of the metals used in a tungsten X-ray tube would be too time-consuming, but certain of the essential characteristics may be mentioned. The filament is tungsten, and, in addition to the properties necessary for its manufacture and preservation at high tempera-

ture, it must have low vapor pressure and high electron emission. The electron emission must be constant for a long period of time. The target must have a high melting point, high heat conductivity, low vapor pressure, and give off "hard" (or short wave length) X-rays when bombarded by the electrons emitted by the filament. It should be capable of being almost completely de-gassed — surely a combination of properties beyond the imaginings of a generation ago.

Long-Time Trends

So much about non-ferrous metals today. How about tomorrow? De Launay in 1908 suggested a normal order of metal exploitation as follows: "If we visualize any one of these new countries whatever, we see it, on the average, realize successively an age of gold, then of silver, then of copper, then of lead, then of zinc, and then of iron." In 1929 Hewett extended De Launay's generalization for non-ferrous metals and suggested the diagram shown herewith.

Hewett's Diagram Showing Stages in the Development, Exploitation and Decline of a Country's Mineral Resources. No significance is to be attached to relative heights attained by the curves



Hewett wrote, "This diagram indicates five stages, shown by successive culminations of (1) the quantity of exports of crude ore, (2) the number of mines in operation, (3) the number of smelters or refining units in operation, (4) the production of metal from domestic ore, and (5) the quantity of imports of crude ore. I do not insist that the order is invariable, for fortuitous discovery and sundry acts of government can slightly change the order temporarily. I merely urge that this is the normal order of the past."

Both De Launay's and Hewett's sequences depend largely on the rapid depletion of the richer ore bodies.

Applying these generalities, it would appear that most of Europe and the United States are in the age of iron in De Launay's sequence and in or approaching the last stage of Hewett's succession. Two whole continents, on the other hand, Africa and South America, are still in the age of copper and in the second of the five of Hewett's stages.

Notwithstanding many predictions to the effect that the civilized world would, in the not distant future, be scrambling for copper, lead, and zinc ore, the best evidence and a study of supply and potential demand leads to the conclusion that the present generation is not confronted with a shortage of any significant non-ferrous metal. While it seems axiomatic that the exhaustion of the richer ores will, in time, profoundly modify metal economics, this is one of the burdens which we can safely transfer to the shoulders of coming generations. The changes will come gradually, and as any particular metal becomes more scarce it will be used more sparingly.

Iron and aluminum comprise about 5 and 8%, respectively, of the earth's crust. Although the richer and most available ores of these metals will in time be exhausted, the leaner deposits are absolutely inexhaustible. Since the largest tonnages of metal find outlet for structural purposes, it is most fortunate for our descendents that these two metals make a potent structural team.

Although forecasting is hazardous, there is some comfort in making predictions for the *remote* future. Not only is the forecaster relieved of much embarrassment, but the predictions are not necessarily less accurate because of the long time period! Some of these long time relationships follow.

1. The time cannot be visualized when any metal will even be a close second to iron, from the tonnage standpoint. (At present the world pig iron production is 14 times that of all non-ferrous metals combined.)

2. New non-ferrous metal production should increase in comparison with new iron production, at least for several generations. (In this connection observe that the graph on page 20 shows that production of pig iron followed one trend line for 30 years, but another for the last 20, whereas the trend of non-ferrous metal has continued substantially unchanged for the entire 50 years.)

3. Aluminum will eventually be the largest tonnage non-ferrous metal. (It is now surpassed only by copper, zinc and lead.)

4. The time cannot be visualized when any of the major non-ferrous metals will be so far exhausted as to rob industry of the richness in variety and combinations of properties which they make possible.

Near-By Trends

Turning to the near future, it is evident that the metal consumption will not change dramatically in kind "over night." The adjustments which have already been established by rigorous economic processes may be assumed to reflect an approximate temporary balance. For the near term, metal consumption depends, more than on anything else, on the state of business, ferrous and non-ferrous metal production going up and down approximately together.

As we try to picture the probable changes during the next two or three decades, we are confronted with the uncertainties of changes in human habits, new ore discoveries, improved methods of metal recovery, alloying, heat treatment, protective coatings, and the like. The past should, however, serve as an approximate guide to the *trend*, because these changes have been going on since the beginning of history, so the following general observations are offered for what they may be worth:

1. In future use it is practically certain that the engineering suitability of non-ferrous metals will be in much greater proportion to iron than the present and recent past ratio of the consumption of these metals.

2. It is equally certain that the cost factor (which is often the dominating one in metal selection) will give iron preference over non-ferrous metals in many applications where the latter enjoy better engineering suitability.

3. In selecting metals in the future, engineering suitability will gradually be given a greater weight as compared with cost.

Another very important factor is the industrialization of the Far East and the backward countries. If the remainder of the world consumed as much metal per capita as western Europe and North America, the present consumption would be quintupled!

We cannot hope to see such a drastic change in our life time, but a change in this direction is in process as evidenced, for example, in Japan. From now on there will be pressure exerted on the more backward countries in Asia from two sides instead of one — a sort of closing-in movement with America and Japan pushing the movement westward and Europe pushing eastward. We can, therefore, hope to see a further substantial consumption of metal in the backward countries.

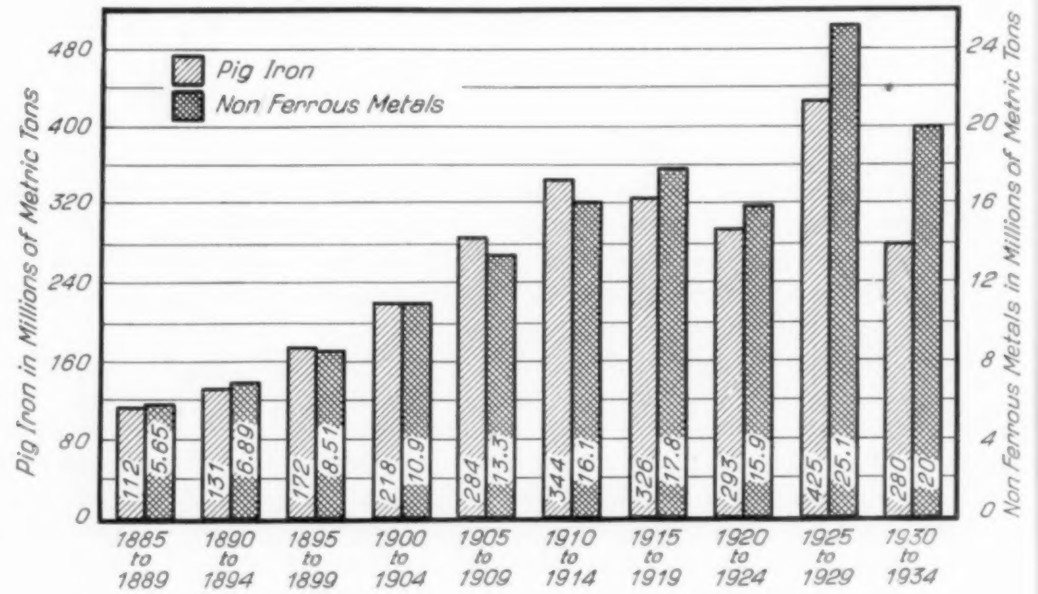
If and when the change becomes substantial, it should bring with it a great change in the non-ferrous industry. The scarcer important metals such as copper, lead, zinc, tin, and nickel should enter a veritable boom period. High prices should accompany large volume. At the same time the need of making the more plentiful metals, iron, aluminum, and magnesium, even more adaptable would offer a challenge to us.

But let us not assume that western Europe and North America have reached a peak either in metal consumption per capita or in population. The urge for a higher standard of living should be strong enough to insure an upward trend even here.

The following, therefore, may be listed as favorable factors in the non-ferrous metal industry of the near future:

1. Because business is at a low ebb it should increase and carry with it an increased consumption of non-ferrous metal.

2. Elapsed time is in favor of non-ferrous metals receiving more than their former share of metal consumption.



Bars Represent Annual Production of Pig Iron and of All Non-Ferrous Metals During Periods Noted. Change in trend for pig iron occurred about 20 years ago. (Vertical scale at right is 20 times the one at left.)

Photo by Margaret Bourke-White for Aluminum Co. of America

3. The western world should not have reached its peak either in metal consumption per capita or in population.

4. Any increase in metal consumption per capita in the backward countries will be exceptionally favorable to non-ferrous metals.

We must admit that the world non-ferrous metal industry, with the exception of gold, is at present in an unsatisfactory state. But in trying to look a few years, rather than a few months, hence, the industry should receive much comfort in these indicated trends.

Unique Position of Gold

The gold industry is at present an exception to the above generalizations. This is not surprising in view of its unique position as a money base and the controlling part played by money in world trade. It is now "on the boom," but we should not be greatly surprised if the gold industry reaches a relatively unsatisfactory state when the remainder of the non-ferrous metals again enjoy prosperity.

This will not be because gold will fail of usefulness, despite keen students of economics who are expounding the view that commodity indexes can perform many of the functions which gold has performed in the past. Inasmuch as its use as a medium of exchange is thousands of years old, we may ask what qualities gold possesses to warrant such dignity. Among them must be included scarcity, durability, plasticity, divisibility, portability, inimitability, ease of recovery from mixtures, ease and definiteness of appraisal, assurance of continuing supply, wide geographic distribution, small current supply as compared with that already mined, and value in the arts. If silver and diamond are considered as possible substitutes, the former is inferior in scarcity, portability, and inimitability. Diamond is deficient in divisibility, ease of recovery from mixtures, ease and definiteness of appraisal, and in geographic distribution. In short, no other material can be found possessing all of these desirable qualities to an extent even approximating that of gold.

But the thought has been expressed that some intangible thing can replace the very tangible gold. In suggesting some of these changes, it is probable that too little regard has been given to the small amount of energy which is required (a very small fraction of one per cent of the current expenditure of human energy) to provide the necessary new gold, so small in percentage that it could scarcely be found in world costs. Yet the service gold performs is stupendous. It serves as a moderate wealth storage, but its main function is to measure world trade transactions. It equates every world currency with every other, whether or not the various countries have a fixed gold standard.

There are only two conditions, it seems to me, which could evict gold from its well-fortified trenches. One is that the whole world might some time be dominated by one government, and the other is a condition of perfect and continuous trade equilibrium among all countries. Political history is against the former and economic history is against the latter. When we consider that not for one second during the past several thousand years has man ceased to put a high value on gold, the burden on those who would dethrone it is indeed heavy.

IRON AND STEEL

of better qualities

By Robert S. Archer
Metallurgist
Republic Steel Corp.
Chicago, Ill.

WHILE 1933 witnessed the curious circumstance that the value of the world's production of gold exceeded the value of the world's production of pig iron (both figured on American prices), it can be assumed that pig iron will normally occupy first place among the metals from the standpoint of dollar value. It might be almost said "first place from any standpoint," for it is refined into steel and used direct in innumerable cast products.

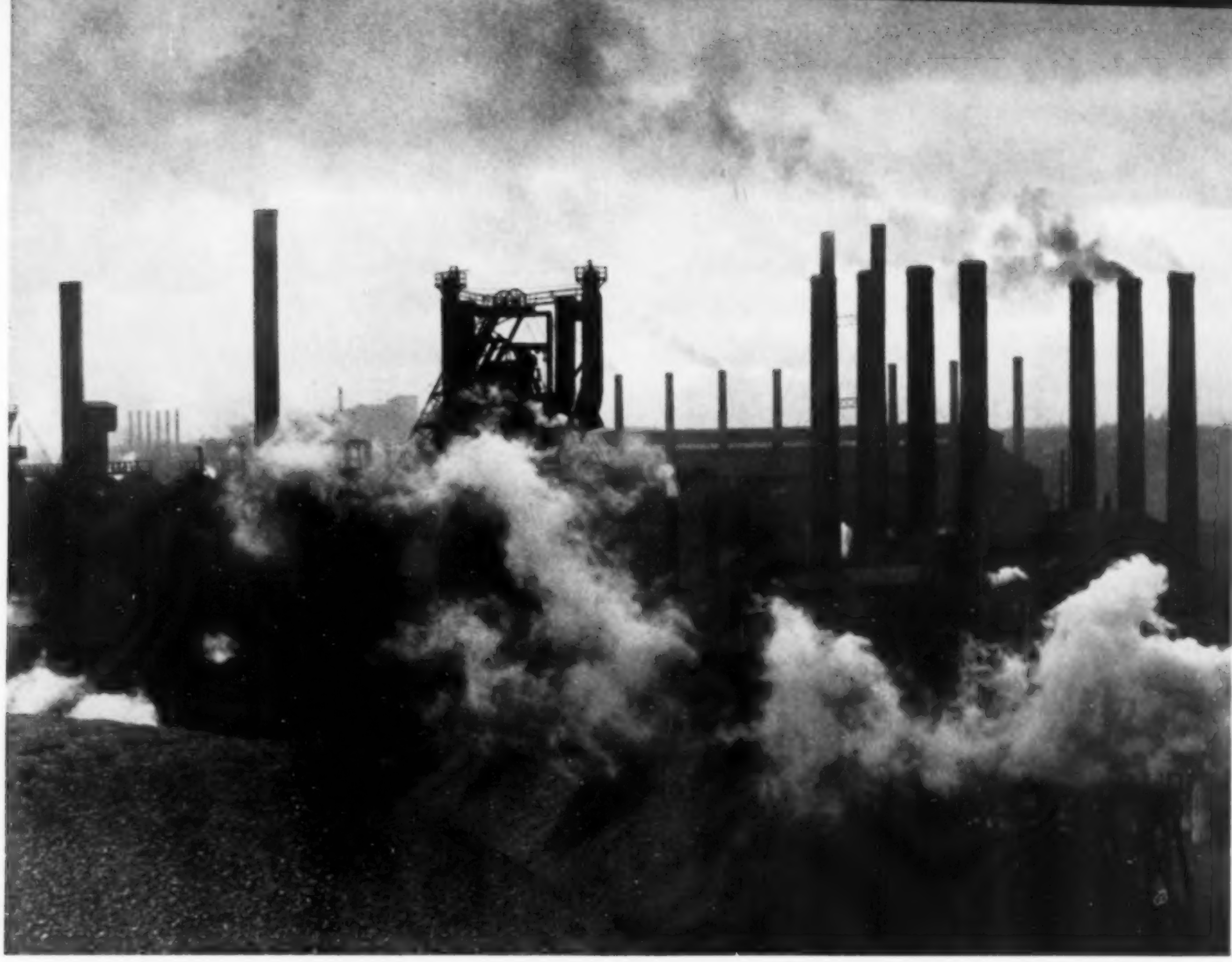
Castings deserve particular attention because for certain applications where the requirements of service can be met by either castings or wrought products, there is a constant competition between gray iron, malleable, or steel castings and forgings, stampings, and welded assemblies. Since the question is largely one of cost, it may be of interest to consider the relation of the business cycle to the problem.

Prices decline during depressions, but we find that for good economic reasons prices of castings generally decline more rapidly and to a greater extent than those of the competitive wrought products mentioned. The practical conclusion is that it is apt to be profitable during the early stages of a depression to look for opportunities to replace wrought products by castings, while the reverse is apt to be true during an upward trend in business. It is perhaps significant that the cast camshaft and crankshaft were depression developments.

This is part of an address prepared, like the one by Dr. Jeffries on page 17, for a meeting of Mechanical Engineers at the last Metal Congress

There has been important progress in cast iron and in malleable. For general foundry work, there has been a revival of interest in the lower carbon, "high test" irons, although such irons seem to have been produced in certain foundries long ago. The introduction of electric furnaces into iron foundries has, however, provided higher superheating of the metal, and the addition of alloys has still further enlarged the field for high strength and high grade iron castings. Molding practice has also improved remarkably.

Alloy gray irons have come into rather extensive use. Nickel has been employed particularly to give greater uniformity of hardness in sections of varying thickness; chromium largely for wear resistance; molybdenum for increased toughness, refinement, and greater machinable hardness. A notable austenitic iron is



Better Steel and More of It, Is the Undoubted Future Trend
Henry Mayer, the photographer, calls this "The Mill at Sunset"

known as "ni-resist"; it contains about 14% nickel and 4% copper, and is characterized by corrosion resistance, non-magnetic qualities, thermal expansivity about 50% greater than ordinary iron, and relative freedom from growth and scaling at higher temperatures.

Some of the desirable properties of castings obtained by the use of alloys can also be obtained without alloys, by careful attention to design and foundry practice. When patterns, machine shop fixtures, and manufacturing processes are once established, however, and a need for some improvement in the castings develops, it is often cheaper to add alloys than to alter the other established arrangements. And, of course, some of the properties of alloy cast iron could not be duplicated without alloys.

The more common grades of malleable castings, which are fully annealed to ferrite and temper carbon, have not undergone much change in recent years, except for the gradual improvements in practice and control which have characterized the whole metal industry. It is an old practice to harden malleable castings for certain purposes by reheating to above the critical temperature and quenching. It has also been known that a combination of high strength with low ductility can be obtained by incomplete annealing, that is, by leaving some combined carbon. Castings are now commercial which contain around 0.4% of combined carbon in the form of spheroidized carbide. Rather high strength is obtained with this structure, and the ductility is good, although not as high as that of fully annealed material. The control of the annealing operation is more difficult, since the graphitizing reaction must be arrested at a rather definite intermediate point. For this reason, and because of the necessity for close control of composition and for special annealing equipment, the cost of the new product is higher.

Iron castings are also being produced which are intermediate between malleable and gray iron. Many of these contain about 2.0 to 2.5% carbon and 1.5 to 2.0% silicon, often with alloys such as molybdenum. They may also be heat treated to cause a certain amount of graphitization and change in the form of the combined carbon. While many specific types are made, the general effect is to obtain high strength — often around 100,000 psi. — together with a degree of toughness well above that of ordinary gray iron.

In the steel foundries, low alloy additions

and heat treatment have been employed to an increasing extent for higher physical properties. It is to be noted that the compositions and treatments most suitable for wrought products are not necessarily the most suitable for castings. Perhaps more conspicuous has been the rapid development of high alloy castings for corrosion and heat resistance.

Better Sheet Steel

Of the many post-War developments, one of the most important is the continuous hot rolling of wide strip and sheet. Gradual improvements in practice have resulted in better finish, and the use of normalizing furnaces has improved drawing qualities. The net result of developments in this field is that sheet and strip of improved quality are available, at lower cost and in larger sizes. Probably the greatest single stimulus to these developments was the rapidly growing demand of the automotive industry for body and fender stock.

(Other factors were important, too, particularly the use of wide strip in recent years for the manufacture of electrically welded pipe. The manufacture of tubing and pipe by electrical welding processes has in itself been a major development. Ability to produce the larger sizes at lower cost, and at a higher rate than ever before, caused the rapid expansion of natural gas pipe lines. Recent developments in the hot rolling of small seamless tubes promise improved inside surface and lower cost.)

The quality of sheets for vitreous enameling has undergone marked improvement since the War. The use of open-hearth steel of very low carbon content has distinct advantages. The lower critical point Ac_1 is practically eliminated, and the upper critical point Ac_3, with the corresponding volume change, is raised above the usual temperatures for firing enameled work. The consequent reduction of warpage permits the enameling of larger surfaces, and the substantial absence of carbides at the surface prevents certain defects in the enameled finish.

More Knowledge About Hardening

The hardening of metals has become much better understood, and this has led not only to a better foundation for certain fabricating and heat treating operations, but also to a clearer conception of the functions of alloy elements in steel.

Because of the experimental difficulties incident to observations during very rapid cooling, it was only recently established that the tendency for austenite to transform into martensite is greater at temperatures not far below the critical, say about 1100° F., than at somewhat lower temperatures. Hence, if steel is cooled through this zone rapidly enough to prevent decomposition, then the austenite remains relatively stable until temperatures around 400° F. are reached, and full hardening occurs (except in certain high alloy steels in which austenite can be preserved indefinitely at room temperature). The minimum cooling rate necessary to preserve austenite through the temperature zone around 1100° F. may therefore be considered the *critical* cooling rate for hardening, and a measure of the hardenability of the steel.

The most that can be done to cool a piece of steel rapidly is to chill its surface quickly and keep it cold. The cooling of the interior of the piece then takes place by conduction of heat to the surface, and the section of the piece does not have to become very large before the rate of cooling of the interior is definitely limited by the thermal conductivity of the metal rather than by the means of quenching. The critical cooling rates of plain carbon steels are quite rapid, so these steels can be fully hardened through and through only in small sections.

This brings us to the principal function of alloy elements in the moderate amounts used to improve the mechanical properties of steel. This function consists in greatly decreasing the critical cooling rate, thus permitting large sections of steel to be fully hardened. The alloy elements most commonly used for this purpose are manganese, chromium, and nickel. The principal effect of these elements is then described as an increase in "hardenability," "depth of hardening," "penetration," or "air-hardening qualities." Molybdenum also contributes substantially to these qualities, though perhaps not quite in the same way.

Another important advantage of the fact that these steels can be hardened by slower cooling rates lies in the decreased internal stress, warpage and cracking which result from higher rates. The temperature differences within a piece of metal are less during slow cooling than during rapid cooling, and there is more time for the relief of stress by plastic deformation. Much of the internal stress resulting from rapid hardening is due to the expansion which accompanies the change from gamma to alpha iron. During

hardening of alloy steels at lower rates, as on quenching in oil, there is more opportunity for carbide formation to take place simultaneously with (or immediately following) the change to alpha iron, so that the shrinkage due to the former may partially neutralize the expansion due to the latter, and thus reduce the internal stresses.

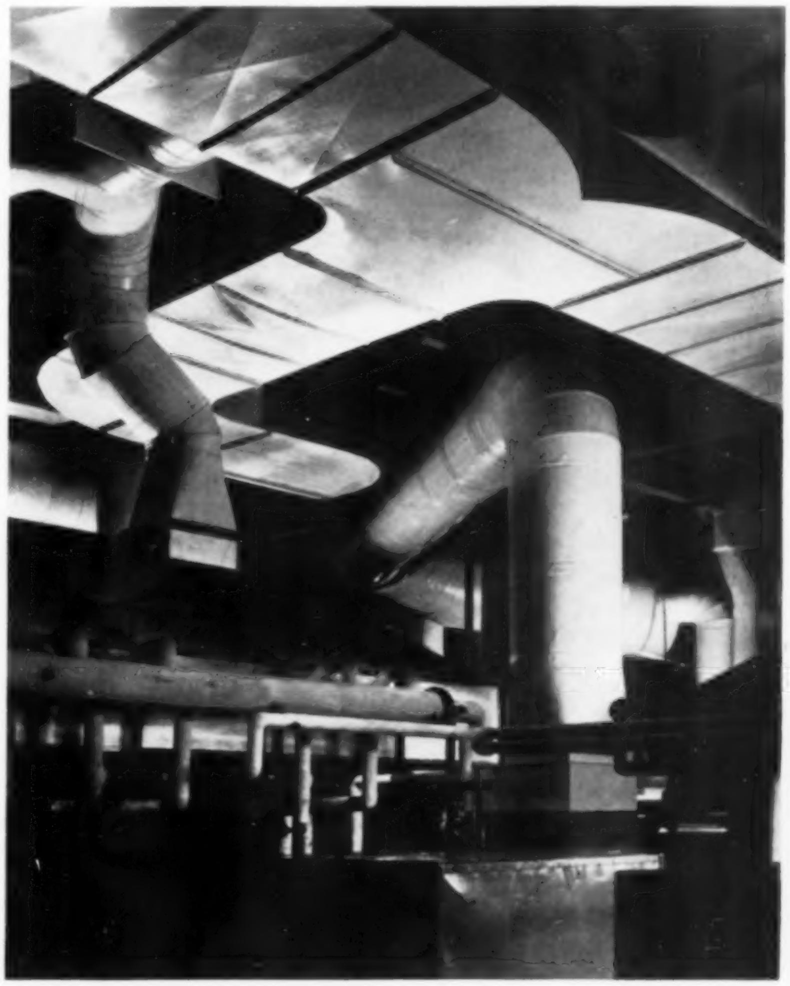
There is another important function of certain alloy elements of the carbide forming type. The carbides of tungsten, molybdenum, chromium, and vanadium show more resistance to growth on heating than does the cementite of plain carbon steel. Small particle-size is in itself a hardening factor, and also contributes indirectly to hardness by obstructing grain growth in the ferrite matrix. Hence the addition of these elements to steel reduces the softening effect of reheating after hardening. Higher drawing temperatures are therefore used for a given tempering effect. This probably results in more complete relieving of internal stresses, although it must be considered that there is an increased resistance, at a given drawing temperature, to the plastic deformations by which stresses are reduced. Higher drawing temperatures may have certain other beneficial effects, such as, perhaps, the healing of very minute cracks formed during hardening. At any rate, it seems that the use of high drawing temperatures does contribute to the toughness of heat treated parts. The alloy elements mentioned are also valuable in steels to be used at elevated temperatures.

Grain Size Control

Perhaps the most important metallurgical development of the post-War period is that of grain size control. It, however, needs no more than mention in a publication of the American Society for Metals, since members of this Society have had such a prominent part in this advance.

The inherent resistance to grain growth of the "fine-grained" steels seems to be due to the presence of very small particles of one or more constituents which do not dissolve or coalesce during the heat treatment involved. Such particles may act as nuclei for the formation of austenite grains on heating through the critical, or as obstructions to grain growth. It is known that undissolved carbide particles, especially in high carbon steels containing the strong carbide-forming elements, cause small grain size. In the steels made fine-grained by aluminum additions, it is thought that the refining agent is aluminum oxide, nitride, or carbide. Vanadium is also a powerful grain refiner, and the effective form may again be oxide, nitride, or carbide.

The knowledge developed in recent years from studies of grain growth characteristics, normality, and hardenability has done much to dispel some of the mystery surrounding that rather vague quality of steel, particularly tool steel, which used to be referred to as "body." Somewhat independently of this new information, users of tool steel were at the same time developing the practice of buying tool steel by specification instead of by brand name. This practice has, on the whole, been successful, but it is to be remembered that some of the value of fine steels still depends upon the skill and the integ-



A Little Sheet Metal in Exhaust and Air Conditioning Systems at Eastman Kodak Co. Photo by H. L. Irwin for Applied Photography

rity of the steel maker in matters which are difficult to control by means of specifications and inspection.

At the time of the World War, certain types of alloy steel were well established for applications requiring a combination of high strength and toughness. These were, principally, (1) nickel steels containing up to about 5% nickel; (2) chromium steels containing up to about 1.5% chromium; (3) nickel-chromium steels containing up to about 4% nickel and 2% chromium; and (4) chromium-vanadium steels containing around 1.0% chromium with about 0.18% vanadium. Silico-manganese steel is clearly an alloy steel technically, but is not always so classed commercially. Probably the outstanding trend since the War has been in the use of molybdenum. This element is generally used in amounts from about 0.1 to 0.4%, and is commonly added in conjunction with nickel, chromium, or nickel and chromium. In the nickel and nickel-chromium steels, molybdenum promotes deep hardening, and also seems to have a rather specific effect in reducing or eliminating temper brittleness. In any steel, it favors the retention of hardness and strength at elevated temperatures. Considerable development work is going on at the present time on carbon-molybdenum steels, usually with somewhat increased manganese contents.

Special alloy steels have been developed for nitriding, and surfaces are obtained which are distinctly harder than hardened tool steel, and also moderately resistant to rust. These steels have worked out very well in certain special applications.

High Alloy Steels

Considering the high alloy steels, the outstanding developments have been in the field of corrosion and heat resisting steels containing high percentages of chromium, with and without high percentages of nickel. Many problems have had to be solved, beginning with the difficulties of fabrication and finishing. For instance, in the austenitic steels, of the 18% chromium, 8% nickel type in particular, intergranular corrosion and embrittlement sometimes occur after exposure to temperatures around 1200° F. Certain early failures were explained in this way. These phenomena are now much better understood, and can be avoided by proper heat treatment, proper application, and control of chemical composition.

A comparatively new field for stainless steel which promises to become very important is that of light weight construction, where it competes with the light metals, aluminum and magnesium. In cold rolled 18-8 alloy, tensile strengths of 150,000 to 225,000 psi. are obtained. This is approximately equal, weight for weight, to the strength of duralumin in tension. Young's modulus for steel is about three times that of aluminum, and the weight ratio is less than three. Hence steel is stiffer in tension with respect to elastic deformation than duralumin, weight for weight.

The design of structures is, however, more often based upon rigidity under transverse loading than upon strength or rigidity in tension. It is possible to build light structures of high strength steel by getting the bulk of the metal away from the neutral axis. This often results in the use of material so thin that ordinary steel would be objectionable from the standpoint of corrosion, and it is this objection which has been overcome by stainless alloys.

Both stainless steel and the light metals have their specific advantages for light construction. Aluminum is especially suitable for sheets, because it would be difficult to build up a steel structure of this form and of equal weight and stiffness. Likewise aluminum and magnesium are suitable for certain forgings, such as aircraft engine crankcases and nose pieces, because of the difficulty of building up equivalent structures in steel. Where the built-up steel structure is practicable, however,

(Continued on page 64)

Robert S. Archer

Vice-President of American Society for Metals. For many years he was with the Aluminum Co. of America, Cleveland. Before joining Republic's staff he was chief metallurgist for A. O. Smith Corp., Milwaukee. Photograph by Maurice Seymour

BETTER WELDING ROD

means better welded joints

By J. H. Critchett
Vice-President
Union Carbide & Carbon
Research Laboratories

OXY-ACETYLENE welding of steel involves heating the metal from room temperature up to and beyond its melting point. Hence in a complete metallurgical study of the process it is necessary to consider all of the effects that can take place in steel over that entire temperature range both in the solid and liquid conditions, a study which covers the entire art of steel making and heat treating. This is obviously beyond the scope of a single paper, and it is therefore proposed merely to point out certain important analogies between oxy-acetylene welding and open-hearth steel making, and to show how best practices in the latter have their counterpart in processes which have greatly improved the quality and economy of the ox-welded joint.

As is well known, steel reacts with the oxygen of the atmosphere at all temperatures. At ordinary temperatures the action so commonly recognized in rusting takes place slowly. At furnace temperatures the tendency for iron to react with oxygen markedly increases, resulting in an adherent oxide scale which affects greatly the steel just below the surface. At the junction of scale and steel, the carbon of the hot steel begins to react with the oxide of the scale at the mutual surface or interface, the carbon being converted to gaseous carbon monoxide and escaping. As the surface of the metal thus becomes decarburized, more carbon migrates through the solid steel to its decarburized surface, and the above reaction continues so that the carbon may be almost completely removed from the steel to an appreciable depth.

All this is in solid steel and solid scale. When the metal becomes molten, these reactions can take place at an even faster rate. Iron oxide becomes soluble in the liquid and hence is in a condition to react much more rapidly with carbon and certain other elements contained in the molten steel. At the melting stage in the making of a joint by fusion welding the analogy between it and the end of the melting period in open-hearth steel making operation is quite close. In the furnace a reaction goes on between carbon in the liquid steel and iron oxide or added iron ore, giving the bath a gentle boil, and the carbon is finally reduced to a low percentage. The manganese passes back and forth between slag and metal.

Part of a discussion of the metallurgy of oxy-acetylene welding of steel, presented to the 35th annual convention of International Acetylene Asso.

combining readily with non-metallic impurities in the steel and carrying them out of the steel bath into the slag, thus acting as a very effective cleansing agent.

Perhaps the simplest product of an open-hearth furnace is so-called rimmed steel such as would be produced if the furnace were tapped at the end of the operation very roughly outlined above, except for the addition at the end of a small further amount of manganese. However, rimmed steel is simple only in the number of constituents involved — actually, it is a type of steel which calls for the highest skill of the melter. It depends primarily on a definite content of iron oxide for correct behavior in the mold and the content of oxide varies with carbon content and temperature of the steel and the size of the ingot being cast. When well made, there is a gentle effervescing in the mold which results in an ingot with an exceedingly clean and dense surface, but containing many small cavities or blowholes toward its center. Such a steel when rolled into sheet or drawn into wire is well adapted to the production of many articles which must have a good surface. Its strength and other physical properties, even when perfectly made, are strictly limited by the fact that only low carbon steels can be rimmed and the presence of alloying elements is prohibited by the nature of the operation. If rimming steel is imperfectly made, the less said about it the better!

Ripple Welding With Neutral Oxy-Acetylene Flame — a Close-Up of Blowpipe, Tip, Rod and Puddle

Welding Rods of Soft Steel

The above outline of principles involved has been necessarily cursory and abbreviated, but it is hoped sufficiently clear for the purposes of this paper. Let us see how they apply to oxy-acetylene welding, giving attention first to the older and newer welding rods and weld metal made with them.

Disregarding the early use of Norway iron, the first oxy-acetylene welding of good quality (strength approaching that of mild steel) was done with low carbon steel rods containing a minimum of other elements, wherein the welding operation is quite analogous to the making of rimmed steel. In heating the base metal and welding rod to the fusion point, both become coated with scale. Several effects resulting from this fact have a direct bearing on the manipulation during welding and on the quality of the finished weld:

First, the scale on the surface of the metal melts at a lower temperature than the steel itself, hence must be removed from the surface in order to get adhesion between the added metal and the base metal (as is necessary for a metal-to-metal joint). In order to be certain that this had been accomplished, the operator melted a considerable amount of base metal alongside the joint, giving a wide weld and using an excessive amount of oxygen and acetylene. Also, in order to make sure that this liquid iron oxide was completely eliminated from the weld, it was necessary to carry the temperature of the metal well above its melting point in order to obtain the liquidity that comes with higher temperatures. Further, the oxide dissolved in the metal reacted to some extent with the carbon, giving rise to blowholes, and the complete absence of silicon, manganese, and other deoxidizing elements prevented a cleaning action such as goes on in an open-hearth furnace during the manufacture of high grade steel. The carbon content of the rod had to be low to avoid excessive reaction between it and copious amounts of iron oxide which were present, else it would have led to a serious number of blowholes; the scale on the surface of the base metal further decarburized it, thus lessening the amount of strength-giving carbon in the weld; and the sluggish flowing qualities of the weld metal (substantially pure iron) led to the ripple type of weld, since the metal had to be *blown* into place. An excellent study of the operation is given in the photo alongside.

In spite of all these difficulties these welds served the early days of the industry well. To get good welds required a high degree of skill on the part of the welding operator, and led naturally to the temperamental nature of that worthy gentleman.

With growth of the welding industry and in-

creased knowledge of its difficulties and needs came realization of the important role played by the rod aside from that of simply supplying metal to fill the scarf or vee. Rods were devised containing the elements on which the steel manufacturer relies for producing high grade steel.

Slag Forming Elements in Rod

By the addition of silicon and manganese the gas-forming reaction between carbon and iron oxide was minimized and replaced by a reaction between these metallic elements and iron oxide. Since the products of these reactions are solid or liquid rather than gas, they do not result in blowholes. With the proper balance between the silicon and manganese contents in the welding rod, the ratio of silica to manganese oxide is controlled so as to produce a fluid slag of manganese silicate which readily floats to the surface, effectively cleansing the weld metal as it does so and then blanketing it against further oxidation.

These improved welding rods had far-reaching influence on the art. Eliminating the causes of the undesired reaction between carbon and iron oxide makes it possible to increase the carbon content of this type of rod (and consequently of the weld metal) to a figure comparable to the usual structural steel. As a consequence this type of rod yields sounder welds of materially higher strength than the best obtainable with rods of Norway iron or low carbon steel. The strongly reducing elements in the rod remove the scale on the base metal without leading to further troubles, thereby presenting a clean surface for the weld metal to adhere to, making it unnecessary to melt deeply into the base metal. Further, the increased carbon, silicon and manganese in the weld metal materially lower its melting point so that it flows well and is easily placed where desired. All of these factors reduce the strain on the operator and the amount of work that the welding flame must do, leading to better technical results and, equally important, lower production costs.

Welding With Carburizing Flame

More recently (within the last year, in fact) a still further advance has been made, this time in the technique of welding, which, coupled with the improved rods, now makes oxy-acetylene welding a very different procedure from that of yesterday. By using a carburizing or excess acetylene flame, the welding blowpipe is made to perform an added function. The new procedure depends on the fact that carbon very effectively reduces iron oxide, that hot steel readily absorbs carbon, that carbon migrates through hot steel at a rapid rate, and that high carbon steel has a melting point several hundred degrees lower than low carbon steel.

In it the carburizing flame is directed backward against and over the completed weld, but in such a way that the excess acetylene flame spreads out over the scarf or vee in advance of the molten puddle. Any iron oxide that may be on the surface of the metal is reduced by this

Backward Welding at High Speed, With Carburizing Flame Directed Against Rod; Tip Has Auxiliary Openings for Preheating Metal in Vee

flame to a spongy type of iron which readily absorbs carbon from the flame. The melting point of this thin and porous layer falls as the carbon increases in it, until when fully carburized, it is nearly 700° F. below the melting point of carbon-free iron.

Promotes Dense Metal in Joint

This very simple welding procedure thus serves to eliminate the troublesome and gas-producing scale in advance of the welding operation so that blowholes from this source are prevented. It also adds an appreciable amount of strengthening carbon to the surface of the base metal which, without this treatment, would have been decarburized by its oxide surface.

Moreover, the highly carburized surface of the scarf is easily brought to a "sweating condition" (incipient melting) in advance of the welding operation without any particular attention being paid to it by the operator. This condition is perfect for forming the union between liquid metal from rod and base metal. There is no need for melting into the scarf to secure clean metal for this union and the operator's attention needs to be directed mainly to melting the rod. As a result, the groove can be narrowed, hence less rod is needed to fill it, and this, together with the elimination of melting the scarf, leads to rapid, easy welding at a reduced cost for materials. The highly carburized surface of the base metal is rapidly absorbed by the added metal and the carbon diffuses uniformly through the weld while it is still at a high temperature, giving a uniform, strong and ductile joint.

Another real advantage is that it can be made semi-automatic for certain applications. The reduced attention required from the operator at the focal point of the welding enables the construction of an apparatus by which the rod is fed by gravity as needed; several flames are provided, each designed to carry out a particular function of the operation — reducing, carburizing, preheating, and melting. As would be expected, all this leads to an ease and speed of welding impossible under earlier methods.

This matter of economy may best be illustrated by quoting from the Report of the Oxy-Acetylene Committee to this 35th annual convention of the International Acetylene Association. It quoted from records made in 1924 on the first big all-welded gas line, constructed by a crew of 220 blowpipe operators (then an unprecedented number).

"Standards of productivity at that time called for four to five welds per day on 16 and 18-in. pipe, rather lighter in weight than standard. We are now expecting each welder to produce from 20 to 25 joints per day on 18 or 20-in. pipe, and as many as 60 or 70 joints per day on 6-in. Strange as it may seem, the torches do not use appreciably more oxygen and acetylene per hour of operation than was required ten years ago. The welds are somewhat narrower, but we are depositing at least three times as much metal for the same quantity of gas in the flame.

"It is also a startling thing to compare the cost sheet for a welding job with the costs of ten years ago, or a little further back, say immediately after the War. At that time it was unusual to include in an estimate any items other than the welder's time and the oxygen and acetylene. The welding rod (which was then of the Norway iron type costing about 7¢ per lb.) was considered to be such a small part of the total that it could safely be left out of the calculation of costs.

"With the development of high grade welding rods, reduction in gas cost, and improvement in efficiency of applying the flame, the net price to the supply companies now indicates that the welding rod exceeds in value the cost of both gases! Inasmuch as the welding rod for working on ordinary steel has increased in value by approximately 100%, it is obvious that there has been a marvelous decrease in the other costs. Even in the item of labor there has been a marked relative decrease due to the much more rapid application of the weld metal into the joint."

J. H. Critchett

Prior to joining the Carbide organization, many years ago, Mr. Critchett was an electric furnace man. He is now vice-president of Union Carbide and Carbon Research Laboratories, Inc.

PRECIPITATION HARDENING

its scope and possibilities

By Paul D. Merica
Assistant to the President
International Nickel Co.

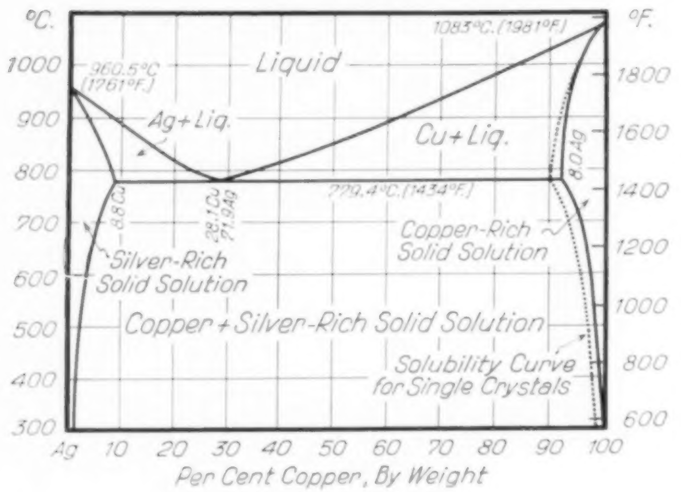
THIS SUBJECT is known under a number of aliases, of which the above title is only one. "Precipitation hardening," "dispersion hardening," "age hardening" — all of these names are currently used, and reflect one or another of the interesting aspects of the subject. None, unfortunately, is a complete revelation of it. Indeed there are not wanting those scientists who allege that the aliases are all largely frauds anyway, and that the subject's real name and origin are not known, even now!

However, let us be polite and use all of its names as occasion requires; and first of all that of "precipitation hardening," since of them all it perhaps best describes, and will serve to introduce, that outwardly simple phenomenon to which the names were originally given, and which first attracted attention in connection with the alloy duralumin.

In order to describe this phenomenon briefly, it will be best to choose a simple example such as a silver-copper alloy corresponding approximately to sterling silver.

Metallic silver dissolves 8.8% of copper in solid solution at 780° C. (1435° F.); the copper solubility diminishes, however, with decreasing temperature, dropping to perhaps 2% at 300° C. (600° F.) and below. When an 8% copper-silver alloy is slowly cooled from 750° C., copper is therefore continuously precipitated from solid solution, leaving at 300° about 2% still in solid solution and 6% in the form of precipitated free copper. The alloy after this treatment is moderately harder than pure silver.

Precipitation of the excess copper may, however, be prevented by cooling fairly rapidly from 750° C., after which treatment the copper is retained in supersaturated solution at ordinary temperatures. In this condition the alloy is still soft, softer, indeed, than in the slowly cooled condition. This supersaturated solution of copper in silver shown in the left micro on the next page is unstable in the sense that it will precipitate excess copper if tempered for a few hours at about 300° C. Because of limited diffusion velocity at these temperatures, the copper is precipitated, not in relatively coarse particles as during slow cooling, but as a shower of finely dispersed particles of submicroscopic size, which cause the microstructure to etch much more rapidly. The alloy after such treatment is considerably harder than after slow cooling or after quenching. Actual Brinell hardness values are about as follows:



Copper-Silver Equilibrium Diagram. This system has been extensively studied, and the lines showing phase changes and limits of solubility are plotted by Cyril Stanley Smith in National Metals Handbook, 1933 Edition, page 1168, according to most probable values

Hardness of Sterling Silver

As slowly cooled	Brinell	70
As quenched		55
Quenched and aged at 300° C. (575° F.)		110
Quenched and aged at 500° C. (930° F.)		75

Important is the fact indicated in the last line that if the tempering treatment is executed at higher than the optimum temperature, the precipitated copper particles coalesce somewhat, their size is greater, their number less, and the resulting "age hardness" also less. The alloy "over-ages," as we say.

Hardening by *precipitation* and *dispersion* of particles brought about through *aging!* It is readily understood why this type of alloy hardening has received all of its various names!

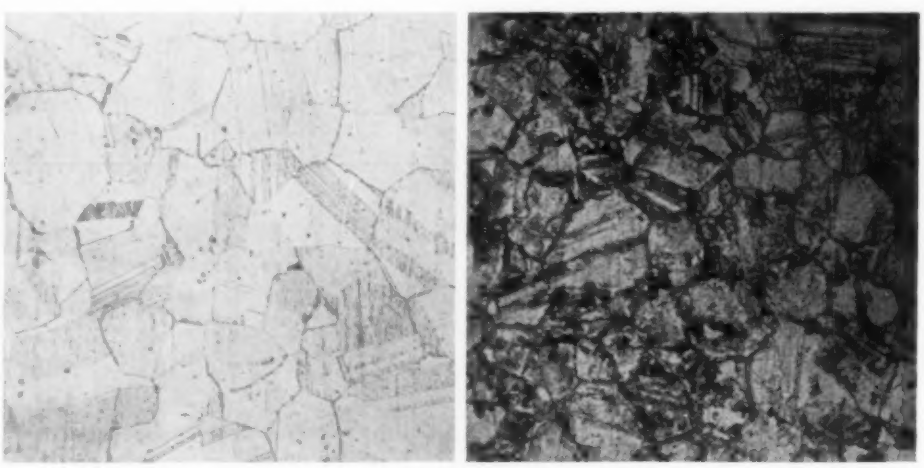
It is found only in alloys and not in pure metals, since segregation of a second metal or constituent is required. The standard heat treatment which induces it comprises (1) annealing at a high temperature long enough to bring about solution of the hardening constituent; i. e. a "solution treatment", (2) rapid cooling or quenching to ordinary temperatures to suppress the normal coarse precipitation, and (3) "aging" either at room temperature or a lower temperature "tempering" to produce the finely dispersed precipitate. It is found only in those alloys in which supersaturated solid solutions are possible; in consequence, only in alloys in which there occur fairly marked changes of solubility of some alloy constituent, as the temperature changes.

The specifications for precipitation hardening thus seem to be very simple (although there are still some tricks about it which we do not wholly understand).

Why Are Aged Alloys Hard?

Now, why are such alloys hard? Or, perhaps more accurately, why are they harder in the heat treated than in any other condition? Perhaps we shall do well to examine this important question through two different sets of theoretical spectacles.

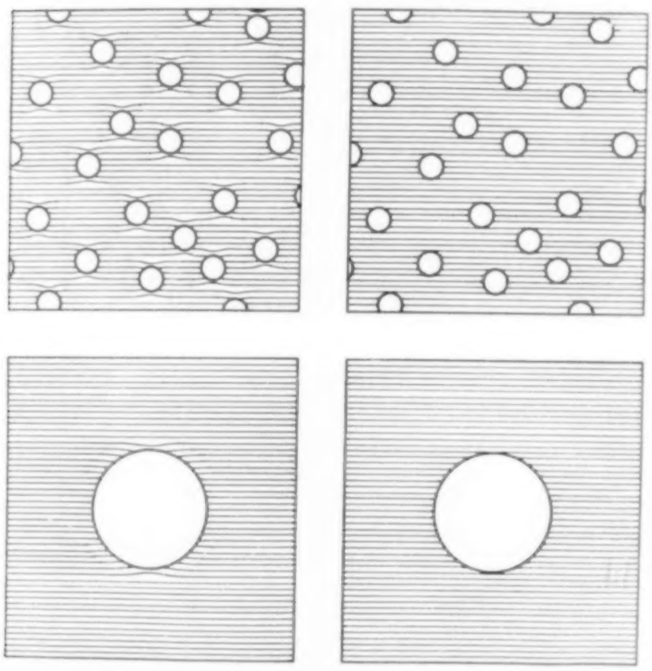
The theory of slip interference held in much favor by American metallurgists was advanced and so ably elaborated by Zay Jeffries and his associates, and teaches that hardness is the result of resistance to slip and to deformation on glide planes in the lattice of the metallic crystals comprising the specimen. Any alteration within this lattice which increases slip resistance also increases hardness, and vice versa. A "stranger" particle in any such lattice obviously breaks the continuity of adjacent glide planes and interferes with slip — it locks or keys those planes. As shown in the diagram on page 33 the total resistance exerted by a set of such particles depends more on their number than on their size, and is



Precipitation of Excess Copper in Sterling Silver (92.7 Ag, 7.3 Cu) At left is material annealed 15 min. at 1400° F., Rockwell B-0.5 hard. At right is same after reheating 1 hr. at 600° F., Rockwell B-76 hard. Magnified 200 ×; Etched with CrO_3 + H_2SO_4. Courtesy R. H. Leach, manager of research and development for Handy and Harmon

consequently at a maximum when the number of particles is largest — namely, when they are in so-called "critical dispersion." (When the particles become so fine as to disintegrate into their constituent atoms, however, these atoms take their places, in true military fashion, on the lattice points of their metallic host and individually exert but little resistance to slip on its slip-planes.)

European metallurgists think of age hardening more in terms of the "distortion" theory,



Diagrams Applying to Two Theories of Hardening; Lattice Distortion at Left and Slip Interference at Right. In either theory the specific effect of a given amount of hardening substance depends upon its degree of dispersion

advanced and supported by the late Walter Rosenhain and others. They suppose that "roughening" of lattice slip planes (in consequence of irregularity of lattice spacing) is responsible for hardness. Such roughening is actually produced even by stranger atoms in solid solution which occupy points on the host lattice, and this accounts for the hardness of solid solutions. When two or more such atoms gather together the distortion of the adjacent lattice is much greater than that produced by a single atom, and supposedly extends through several atom layers, producing thus from a relatively small active nucleus a large ball or volume of distorted or roughened host lattice. Following this conception, it is easy to picture a finely dispersed set of particles, each containing several atoms, as inducing the greatest amount of lattice distortion and consequently the maximum hardness.

Both of these theories yield very useful and stimulating pictures of the age hardening process, and seem to me not widely different. Each merely places emphasis upon different aspects of the hardening mechanism, and in particular upon the part played by the lattice volumes immediately surrounding the activating or hardening particles. As you think about the phenomena of age hardening, you will probably find first the one and then the other the more valuable.

Other Age Hardening Systems

Some irreverent person reading this may well think: "Well! What you tell me is all frightfully simple and I am amazed that we haven't found age hardening alloys early and everywhere. Metallurgists must have been practically as dumb as economists!"

I am afraid we shall just have to grin and bear that jibe! Such alloys are indeed abundant — they are probably the rule rather than the exception in alloy systems, and now that we have the knack of it, it is almost "infra-dig" for a metallurgist not to have his own *pet* alloy of the age hardening variety.

We realize, indeed, that there are even different breeds or strains of such alloys, resembling in some respects the simple duralumin type which I have just described, but exhibiting some important and different characteristics as well. Let us take a brief look at some of the rest of the family.

In the 8% copper-silver alloy, age hardening was possible because of the transformation during cooling of about 6% of the alloy lattice suppressed by quenching and then allowed to proceed at low temperatures. Now there are many other types of transformation in solid alloy systems. Is it possible that age hardening may be associated with any such transformation? The answer is yes, and in many, perhaps most such cases, quite appreciable age hardening response can actually be realized.

A common variety of such transformation is that in which a solid solution changes upon cooling into two constituents; this is the so-called eutectoid transformation. It is illustrated in the beta brasses and bronzes. For example, an aluminum - copper alloy containing 11.9% aluminum when quenched from temperatures above that of its transformation, about 570° C., hardens

upon tempering at temperatures between 400 and 550° C. As shown by the equilibrium diagram all of the beta alloy lattice, stable at the higher temperature, decomposes and transforms at lower ones into new phases or lattices, alpha and delta in this case. The aging hardness of such eutectoid alloys is often predominantly due to the inherent hardness of the precipitated constituents, although "critical" dispersion of these constituents as induced by suitable heat treatment can play an important part as well. For several reasons this type of age hardening alloy has not so far achieved any significant practical importance.

A comparatively rare (but practically a most useful type of transformation in dental alloys) is that in which a phase or lattice type, stable at higher temperatures, transforms completely at a lower one into another phase or lattice. This is true of certain of the gold-copper, palladium-copper, and platinum-copper alloys, and in consequence of this transformation they display age hardening characteristics which, externally at least, are strikingly similar to those of the simple or duralumin type and which are developed by the same kind of heat treatments.

So the duralumin type of age hardening alloy has several relatives, of which — as is the case so often with relatives — some are all right, but others turn out to be not much good! Luckily the duralumin type is the principal branch of the family, and the number of individuals belonging to it not only markedly outnumbers those of the other types, but it is likely always to do so. Probably a hundred different alloys of the principal type have already been described either in the technical or the patent literature and their number would appear to be almost unlimited.

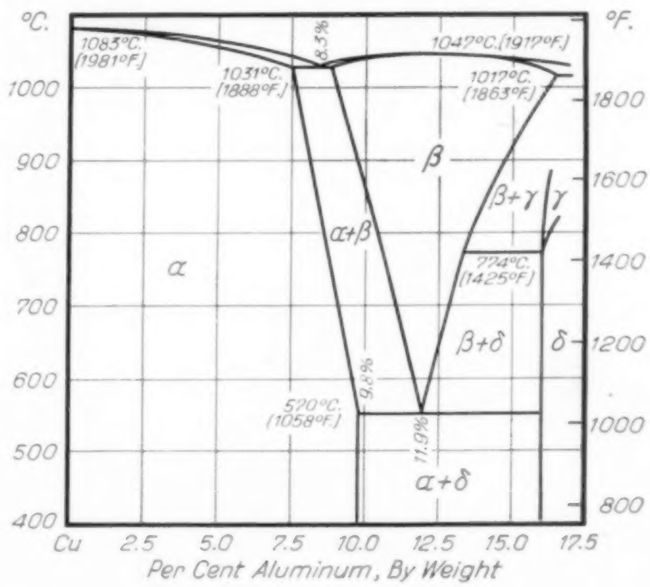
Unique Properties of the Alloys

Now at this point an impatient and possibly Scotch reader may well ask, "Of what value to us are these alloys anyway? I realize," says he, "that they have provided us during recent years with a certain amount of metallurgical entertainment, but are they useful?"

Well, that is a fair question and deserves some attention.

The principal asset of hardenable alloys is, of course, their improved strength and hardness. How much can we improve them actually in this respect? How far can we lift their properties above the usual levels?

The improvement is considerable in many cases and even striking in some. In duralumin (containing about 5% of alloying elements) a tensile strength of 60,000 psi. can readily be obtained by suitable heat treatment. This may be compared with 14,000 psi. for pure aluminum and with 25,000 psi. for the annealed or normalized duralumin or for cold worked aluminum. The increase in strength of duralumin due to heat treatment is about 140%. All this by the addition of as little as 1.5% of magnesium and silicon to aluminum, an alloy addition which alters but



Part of Copper-Aluminum Equilibrium Diagram as Drawn by Stockdale Except That Eutectoid Temperature (750° C.) Is as Determined by Smith and Lindlief

slightly the other fundamental properties of aluminum such as density and corrosion resistance.

Duralumin is not unique in this respect. By the addition of about 4% of aluminum to monel metal an alloy is obtained which is capable of developing, through suitable heat treatment, proportional limits well over 100,000 psi., together with tensile strengths of over 150,000 psi., increases of over 150% and 100% respectively.

Gold-copper alloys hardened by platinum or palladium will develop tensile strengths in the neighborhood of 150,000 psi. through suitable heat treatment alone and without cold working. These are rather noteworthy values when compared with the normal strengths of the constituent metals, of which the highest is about 35,000 psi. for copper.

Even the soft white metals can be improved. A 2.5% antimony-lead alloy can be heat treated to about 12,000 psi. tensile strength; with as little as 0.1% calcium the strength of lead can be

boosted, by adequate aging, to about 7500 psi. These figures may again be compared with that of about 2000 psi., which represents the short time tensile strength of lead itself.

As may be readily imagined, copper lends itself readily to precipitation hardening. When alloyed with about 2.5% beryllium it can be heat treated to about 400 Brinell. This is a very respectable hardness for 97% copper, when it is considered that copper, even when cold worked, does not yield a hardness much above 100 Brinell. Indeed, in this alloy possibly culminates the old, old search for hardened copper, for I don't know of any harder copper that the world has ever known!

These figures will give a fair impression of what is actually possible in age hardening alloys. You will have observed that, although there are some exceptions, they bear on the whole a loose relation to the properties of the base metal or alloy itself. In other words, it is unlikely that a soft metal such as lead can be alloyed and heat treated to the same hardness as copper or nickel. Perhaps a useful, rough way of looking at it (and one which has some theoretical basis) is that one may usually expect hardenable alloys to develop properties comparable with those of the base metals when severely cold worked. The actual values, however, often fall short of this mark and do sometimes also considerably surpass it.

It will be agreed, I think, that in one field at least age hardening alloys have achieved a position of dominating importance — in the field of light aluminum alloys, which duralumin has so revolutionized. The art of light metal construction as practiced today, particularly in the transportation field, would not have advanced to its present status without it. The phenomenon of age hardening has in this field made a contribution of really fundamental importance, meeting a natural economic demand for a light alloy of high strength, with the usual happy consequences.

Paul D. Merica

In War time, when at the Bureau of Standards, Dr. Merica with Messrs. Waltenberg, Freeman and Scott investigated the then new duralumin alloy, and advanced an ingenious hypothesis to explain its strange hardening with lapse of time — a hypothesis which fits most of the additional facts since discovered. Photograph by Bachrach, N. Y.

In several other fields as well, age hardening and age hardening alloys are becoming of increasing importance. I think of the lead alloys with antimony or with barium or calcium, used both for cable sheathing and for bearings, and of the so-called beryllium bronze, sponsored by one of the leading brass companies and used for springs. In a field of a quite different sort, the hardenable alloys of gold, platinum, and palladium are rendering the dentist substantial assistance in building the complicated and tricky structures that enable some of us to continue to eat beef, toast and roughage.

The Marketing Problem

If we look further and are perhaps a bit disappointed that we do not find as much commercial exploitation of the possibilities of age hardening as would seem justified, we must be reminded, I think, that the art is after all very young — not more than a dozen years old. Although a great deal of preliminary and exploratory work has been done in discovering and in inventing new hardenable alloys, it naturally requires time to discover markets for these alloys and to adapt these alloys to their markets.

We should also not overlook the fact that the market for hardenable non-ferrous alloys is apt to be a specialized one. Non-ferrous alloys are generally used for reasons other than those involving hardness and strength — for corrosion resistance or for electrical properties, for example — and uses for them requiring, in addition, higher mechanical properties are apt to be limited with respect to tonnage requirements.

There is one field in which there is still an unfilled, natural demand for high strength in non-ferrous metals *(Continued on page 60)*

NEW ROLE OF TITANIUM

in steels and alloys

By George F. Comstock
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SINCE the discussion of the development of titanium alloys that was published in METAL PROGRESS in 1931, only occasional scattered notes have served to acquaint readers with the additional uses of this element that have arisen from time to time in metallurgical practice.

It was in 1931, or the same year when the publication mentioned above appeared, that general interest began to be focused on titanium as an alloying element in steel. Previously it was known chiefly as a deoxidizer, and it acts so powerfully in that way that almost all the titanium added to a given melt is normally used in combining with the oxygen and nitrogen first in the steel itself and later in its surroundings. Thus the retention of an appreciable titanium content in a finished steel requires not only careful preparation of the bath but also strict attention to the furnace lining, slag used, and amount of exposure to the atmosphere. These requirements have been generally appreciated and effectively met only within the past few years.

Konel Alloys — One of the earliest important applications of titanium as an alloying element was in the "konel" alloys, developed by E. F. Lowry of the Westinghouse laboratories in 1929. Although not a steel, this material merits a description here because it exemplifies in typical fashion the age hardening effect of titanium on other metals. A typical alloy contains about 73% nickel, 17% cobalt, 7.5% iron, and 2.5% titanium, and its best properties are developed after quenching from 1750° F. in water and aging several days at 1200° F. The tensile strength at 1100° F. is then over 75,000 psi. with nearly 25% elongation! Austin and Halliwell in their paper on high temperature alloys of nickel-cobalt-iron, read before the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers in 1932, described a number of modifications of this composition with even more remarkable strength and stiffness at high temperatures. They were convinced that although the presence of cobalt was thought to be necessary, the hardening constituent was most probably Fe_3Ti.

Iron-Titanium Diagram — The age hardening of iron and austenitic steels by means of titanium was investigated and reported by many others at about this same time, notably by Wasmuht and Kroll in Germany (see *Journal*, British Iron and Steel Institute, 1931, II, page 670). In this country Hensel described the "Age Hardening of Austenite" before the Iron and Steel Division, A.I.M.E. in 1931, and Seljesater and Rogers

also presented a paper in *Transactions*, A.S.S.T., in April, 1932, on "Hardness of Dispersion-Hardened Iron Alloys." The latter suggested a change in the classical iron-titanium equilibrium diagram of Lamort in that the solubility of the compound Fe_2Ti in iron should be shown to decrease from 6.3% titanium at the eutectic temperature (2425° F.) to only about 3% at room temperature. This would explain, of course, the ability of iron alloys containing over 3% titanium to age harden by precipitation of Fe_2Ti on reheating of the quenched supersaturated solid solution. Hensel also agreed that marked age hardening required above 3% in his austenitic steels, but Wasmuht found that in the presence of another element such as silicon or nickel the effect could be obtained with less than 3% titanium.

Some of the results secured with titanium in this way might be quoted to show the degree of hardening which may be expected. With 5.4% titanium and an aging temperature of 1100° F., Seljesater and Rogers showed an increase of hardness from about Rockwell C-18 to about C-45. Kroll found age hardening in his nickel alloy steels from about 300 to over 500 Brinell with 3 or 4% titanium. Hensel used austenitic nickel-manganese steels, with 3 to 6% titanium, and found the Brinell hardness was raised from about 170 as quenched from 1830° F. to around 340 after aging several days at 1100° F. Some of Hensel's aged alloys showed rather remarkable tensile properties, such as 142,400 psi. tensile strength with 40% elongation, or 70,000 psi. proportional limit and 107,000 psi. yield point with 13.5% elongation.

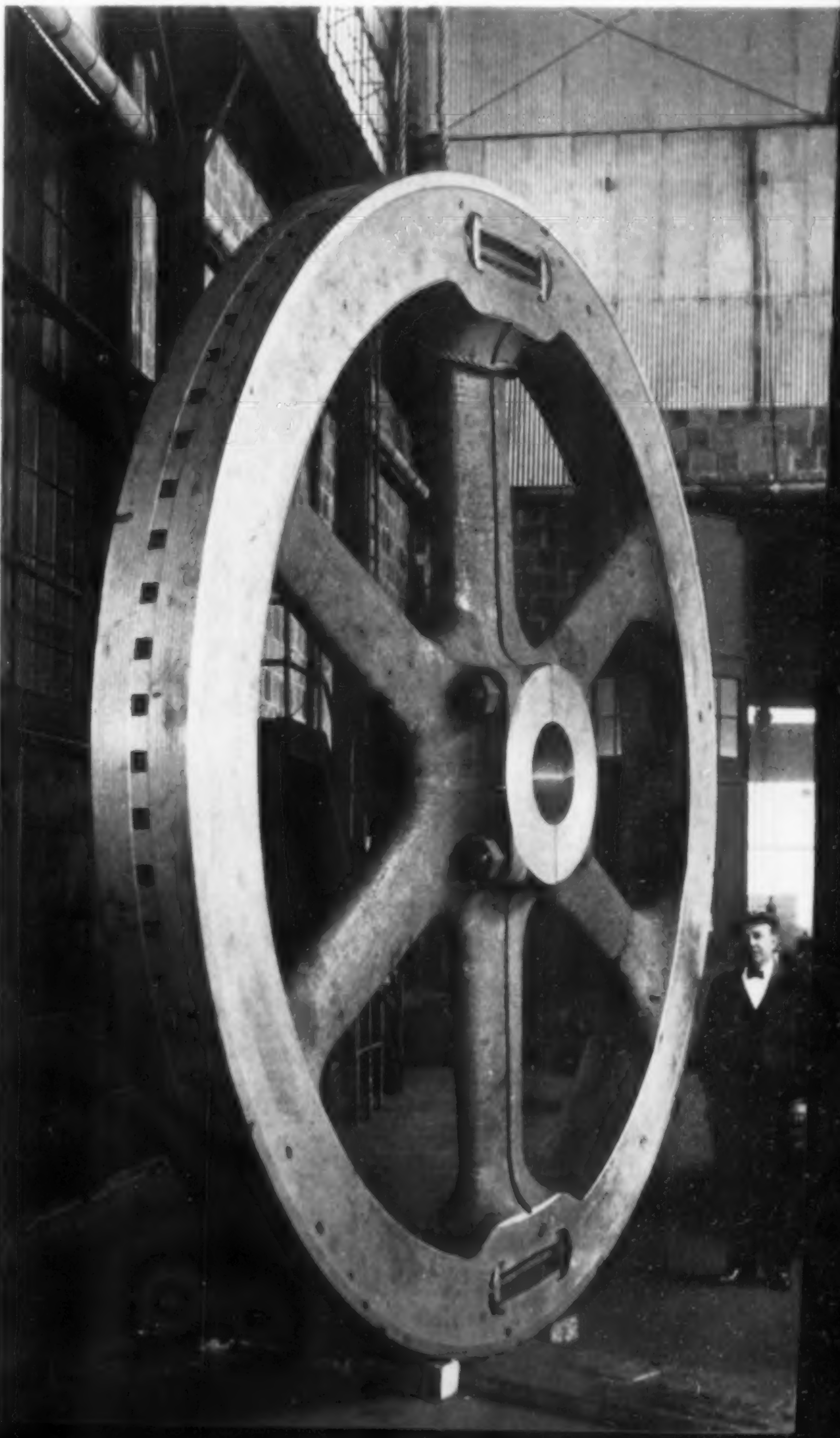
Affinity For Carbon

The property of titanium which is chiefly responsible for its growing use today as an alloying element in steel is its strong affinity for carbon, coupled with the comparatively low solubility of titanium carbide in solid steel. On account of these two facts titanium additions in suitable amount to a low carbon alloy steel virtually serve to remove all the carbon from participation in the physical changes normally experienced in cooling, so that the net result is equivalent to a steel with almost no carbon!

Commercial production of alloy steels with carbon as low as say 0.02% is difficult, and it may often be simpler and more economical to add a certain percentage of free titanium to take care of a reasonable amount of carbon in the finished steel. This action of titanium also permits the use of higher carbon grades of other alloys such as ferrochromium, at an attractive saving in cost. Since titanium carbide has the formula TiC, and the atomic weight of titanium is just four times that of carbon, it requires theoretically four times as much titanium as carbon to combine with all of the latter element in a steel (practically about five or six times, to provide the necessary excess to insure a fairly complete reaction).

Weld Decay — Soon after the sudden rise to popularity of the austenitic stainless steels about seven or eight years ago, it was discovered that when heated to temperatures between about 900 and 1500° F., as is bound to happen at a certain distance from

Fifteen-Ton Flywheel Made From Gray Iron Treated With 1% Ferrotitanium to Refine the Grain. Analysis: 3.38% C, 1.23% Si, 0.79% Mn, 0.18% Ni, 0.20% P, 0.10% S, 0.17% Ti. Tensile strength 34,400 psi. in 1¼-in. diameter section, and 24,600 psi. in 2¾-in. diameter section. Photograph Courtesy of George Ostertag



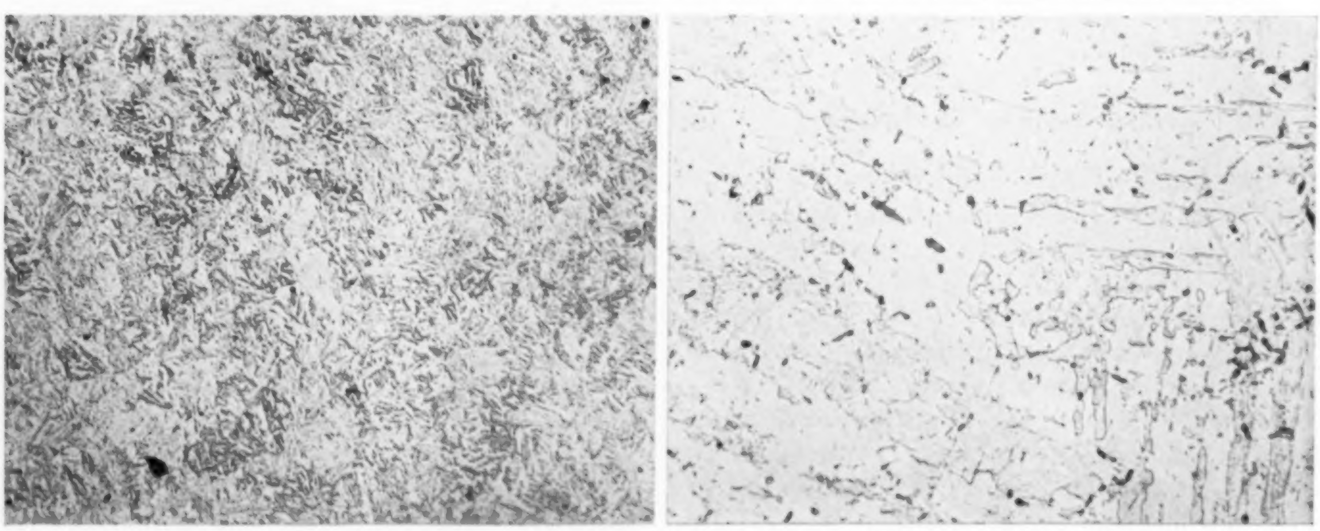
any fusion weld, a peculiar form of deterioration was liable to occur, causing embrittlement and loss of corrosion resistance at the grain boundaries. This defect was first studied in Germany; it was decided that it was caused by precipitation of chromium carbide, which removed chromium from the austenitic solid solution and altered its resistance to corrosion. The localization of this trouble at the grain boundaries was accounted for by the Germans Strauss, Houdremont, and their associates (see *Stahl und Eisen*, 1930, pages 1473 and 1526) by the slow diffusion of chromium as compared with carbon at temperatures below 1500° F., so that the carbon collecting at the boundaries combined with chromium there, removing it from the solution, while the chromium from the interiors of the grains could not diffuse fast enough to the boundaries to maintain the latter in a stainless condition. This explanation is supported by the observation that on heating beyond 1500° F. so that chromium may diffuse rapidly, the susceptibility to corrosion at grain boundaries is overcome.

In seeking a remedy for this disease, as it might be called, that would be practical irrespective of heat treatments, titanium was added to the alloy both in Germany and England, and it was found to be effective in taking care of the carbon so that the austenite was not altered and the corrosion resistance of the steel was maintained even after heating to the dangerous temperature range. British patents on this use of titanium were issued to the Krupp firm in 1930 (No. 337,349), and to Hatfield and Green in 1931 (No. 362,902).

A little later the intercrystalline embrittlement of the 18-8 stainless steels was studied thoroughly by numerous investigators both in America and abroad, and the effect of titanium was included in many of the reports published, so that this use of titanium as an alloying element is probably well known today by readers of Metal Progress. Since the appearance of the papers by Payson before the Iron and Steel Division, A.I.M.E., in 1932, and by Bain, Aborn and Rutherford in *Transactions*, A.S.S.T., 1932, as well as others, on the prevention of intergranular corrosion in the austenitic chrome-nickel steels, the dependence of the defective condition on carbide formation has been definitely established. The whole matter is carefully discussed in The Book of Stainless Steels.

The trouble is not encountered in steels with extremely low carbon content, and the function of titanium is primarily to remove the influence of carbon from the solid solution, as has already been explained. With carbon safely held in combination with titanium, chromium carbide cannot form at the grain boundaries, and chromium is therefore not removed from the solid solution, the corrosion resistance of which is thus maintained at all points.

Micros Illustrating Effect of Titanium in Preventing Air Hardening of High Chromium Cast Steel. Both samples air cooled after 5 hr. at 1650° F., etched with aqua regia in glycerine, and magnified 200 diameters



Analysis				Analysis
Carbon 0.23%	40,700 psi.	Proportional limit	20,500 psi.	Carbon 0.24%
Chromium 5.67%	117,000 psi.	Yield point	44,700 psi.	Chromium 5.11%
Molybdenum 0.51%	212,000 psi.	Tensile strength	70,100 psi.	Molybdenum 0.44%
Titanium none	2.5%	Elongation in 2 in.	8.5%	Titanium 0.81%
	C-45	Rockwell hardness	C-1	

If a large excess of titanium is used in the 18-8 stainless steels over that required for carbide control, an age hardening effect is found, which is not desirable, according to the Germans Bennek and Schafmeister, since the ductility and corrosion resistance are both impaired rather seriously in such precipitation hardened steels. The titanium content is therefore generally held to 5 to 7 times the carbon content in the 18-8 composition, as was explained above, which is sufficient to prevent the formation of chromium carbide in the steel, and to stabilize the alloy against intercrystalline deterioration.

5% Chromium Steel — Another interesting application of titanium as an alloying element in steel was recently described by Becket, Critchett, and their associates in Union Carbide and Carbon Research Laboratories. This is based on the same property of titanium that was mentioned above, namely, its strong affinity for carbon. Steels with more than about 4% chromium and carbon around 0.2% are decidedly air hardening, on account of the effect of chromium in slowing the rate of transformation, so that sorbite, or even martensite, is retained in the steel at normal rates of cooling in air. With no carbon in the steel, of course no martensite could be formed; hence titanium is added to form less soluble titanium carbide, leaving the groundmass of the steel practically free of carbon. In such material the microstructure is always ferrite, in which no air hardening can occur. The effect is shown in accompanying micrographs. One has a martensitic (or perhaps sorbitic) structure and is hard and strong. The other has a ferritic structure with fine titanium cyanonitride crystals, and is relatively soft and not much stronger than mild steel.

Castings of this kind of steel with the proper ratio of titanium to carbon, as tested in the laboratory of the Titanium Alloy Mfg. Co., have been found to be soft and machinable as cast or normalized, while those without titanium are too hard for machining unless drawn and slowly cooled. This, of course, is important in welded structures where annealing and slow cooling are not often practical after welding. Incidentally, it has been found also that this titanium bearing chromium steel has appreciably better resistance to scaling at high temperatures than the steel free of titanium. A series of tests made on cast test pieces of chromium-molybdenum steel containing 0.67% titanium gave the results shown in the table herewith. While the proper heat treatment was able to make pronounced changes in the physical properties, the microstructure remained nearly the same as shown at the right of the pair on page 38, except that the ferrite crystals were refined somewhat.

Physical Properties of Ferritic Chromium Steel Casting After Heat Treatment

Analysis: 0.11% C, 5.44% Cr, 0.45% Mo, 0.67% Ti

Heat Treatment	Proportional Limit	Yield Point	Tensile Strength	Elongation in 2 in.	Reduction of Area	Rockwell	Brinell
None, (as cast)	24,400	31,700	49,500	5.0%	4.3%	B-72	128
A: 6 hr. at 1650°F., air cool	22,200	32,100	58,300	14.5	12.8	B-71	125
B: 5 hr. at 1950°F., air cool	28,800	67,800	80,400	1.5	1.2	B-93	229
C: 5 hr. at 1950°F., water quench	36,800	87,000	107,500	0.5	0.4	B-102	241
C, then 16 hr. at 1150°F. and air cooled	59,800	72,400	83,600	11.0	23.4	B-92	187
C, then 16 hr. at 1650°F. and air cooled	23,000	32,100	59,800	33.5	49.9	B-69	124

Grain Size Control

In connection with the control of grain size in alloy forging steels, the use of titanium as a scavenger has shown interesting possibilities. This is essentially the same application as has been widely practiced for many years in making clean steel that is also thoroughly deoxidized. Titanium does not act the same as aluminum in retarding the growth of the grains in steel, but when aluminum alone is used, the steel is very apt to show serious groups of alumina inclusions as well as a non-uniform structure on deep etching. Ferro-carbon-titanium has been used with considerable success in certain steel plants to replace a part of the aluminum addition for fine grained steels, for the purpose of improving the cleanness and uniformity of the product.

Effect On Copper, Cast Iron and Aluminum

The best description of the effect of titanium on copper was published by Hensel and Larsen

in *Trasactions*, A.I.M.E., Institute of Metals Division, in 1932. They found a very marked age hardening (after the proper quenching and reheating treatment) of alloys containing from about 0.8 to 4.8% titanium, which greatly increased the stiffness and strength and also slightly decreased the ductility of forged bars.

Research recently conducted on cast copper in the laboratory of the Titanium Alloy Mfg. Co. has shown an interesting combination of strength and electrical conductivity after age hardening with titanium. For instance, the conductivity of such castings after heat treatment was found to be around 40 to 50% of the pure copper standard for wire. They also had the following tensile properties: Yield point 23,000 psi., tensile strength 45,000 psi., elongation 25% in 2 in., reduction of area 35%. The titanium content should not be over 1% if good conductivity is desired, and the preferred heat treatment is quenching in water after two hours at 1650° F., followed by a 24-hr. draw at 850° F. The hardness is then about Rockwell E-95, or 110 Brinell. Research is by no means completed on this.

Cast Iron — The application of titanium to cast iron has an entirely different status, being well past the research stage, and growing commercially in a normal manner. The effects of titanium on gray iron have been quite fully described in Metal Progress for August, 1933, and it should not be necessary here to do more than repeat briefly that they are essentially a refinement of the graphite flakes, and a graphitizing effect like that of silicon. Practical use of these effects is being made in many gray iron foundries today for the purpose of "closing the grain" or refining the structure of thick sections, with a resulting improvement in strength; and for avoiding hard spots or chill in thin sections, with a consequent improvement in machinability. An illustration is given on page 37.

How it is possible for titanium to act as a graphitizer in cast iron in view of its strong affinity for carbon in steel, where it forms an especially stable carbide? These two actions occur at different temperatures and therefore are not necessarily inconsistent. The carbide of titanium, forming at high temperatures, does not unite with iron or cementite, while the graphitizing effect on cast iron occurs at a lower temperature and may be due largely to the deoxidizing action of the titanium. Although the explanation for the graphitization may be somewhat obscure, it is nevertheless a well-established result of the use of titanium, has been reported by others, and has appeared in all the author's work with white iron as well as gray.

Recent experience has shown interesting results from furnace additions to electric melted gray iron, as described by R. G. McElwee at the September meeting of the American Society for Metals, Buffalo Chapter. The economy of this application is especially attractive on account of the low cost of the high carbon ferrotitanium which may be used in the electric furnace (and for the successful production of certain difficult castings this alloy has been found practically indispensable). For cupola melted iron a low carbon ferrotitanium, low also in aluminum, is preferable, as its melting point is lower.

At a well-known foundry where such an alloy, known as "TAM Standard Low Carbon Ferrotitanium," has been used in large quantities, the following average results were reported as compared with previous results with the same grade of iron without titanium: (1) Transverse strength increased 15% at 0.1 in. deflection; (2) ultimate transverse strength increased 9%; (3) about the same deflection in transverse tests; (4) Brinell hardness 8 points greater with same machinability; (5) half as much variation in hardness, center to edge of test castings; and (6) at least 12% increase in tensile strength.

These results were obtained at a saving of many hundred dollars in the cost of the alloys used in the iron during the month.

Aluminum Alloys — One more metallurgical use of titanium should be included in this recital, and that is its incorporation in aluminum alloys for degasifying and refining the grain. This was described in 1930 by workers at the National Physical Laboratory in England, but has only recently begun to receive general attention in this country.

The effect of titanium on aluminum alloys is entirely different from its effects on other alloys that have been described above, for it does not deoxidize aluminum, nor cause any hardening in it after aging, nor hold any undesirable impurity in harmless combination. Its function is to form the compound $TiAl_3$ which precipitates from a cooling melt at a comparatively high temperature in the form of fine, isolated needles. On further cooling, these crystals serve as nuclei to start the crystallization of the main body of the alloy, and since there are many such points in a given volume, many crystals are started where otherwise only a few would start, and none of them are then able to grow so large. Sections of small ingots of aluminum alloy adequately illustrate the point.

It requires only about 0.15 to 0.20% titanium in an alloy such as the common 92-aluminum, 8-copper casting alloy to give a much finer grain size with the same pouring temperature and size of casting. The strength is naturally improved in the finer grained material; a gain of 10 to 25% may be attained. Partly as a result of the finer grain, and partly due to a degasifying effect (which is less easily explained but equally real), resistance of titanium-treated aluminum castings to leakage is found to be much better than without the titanium. This result is, of course, of the greatest practical interest to many foundries.

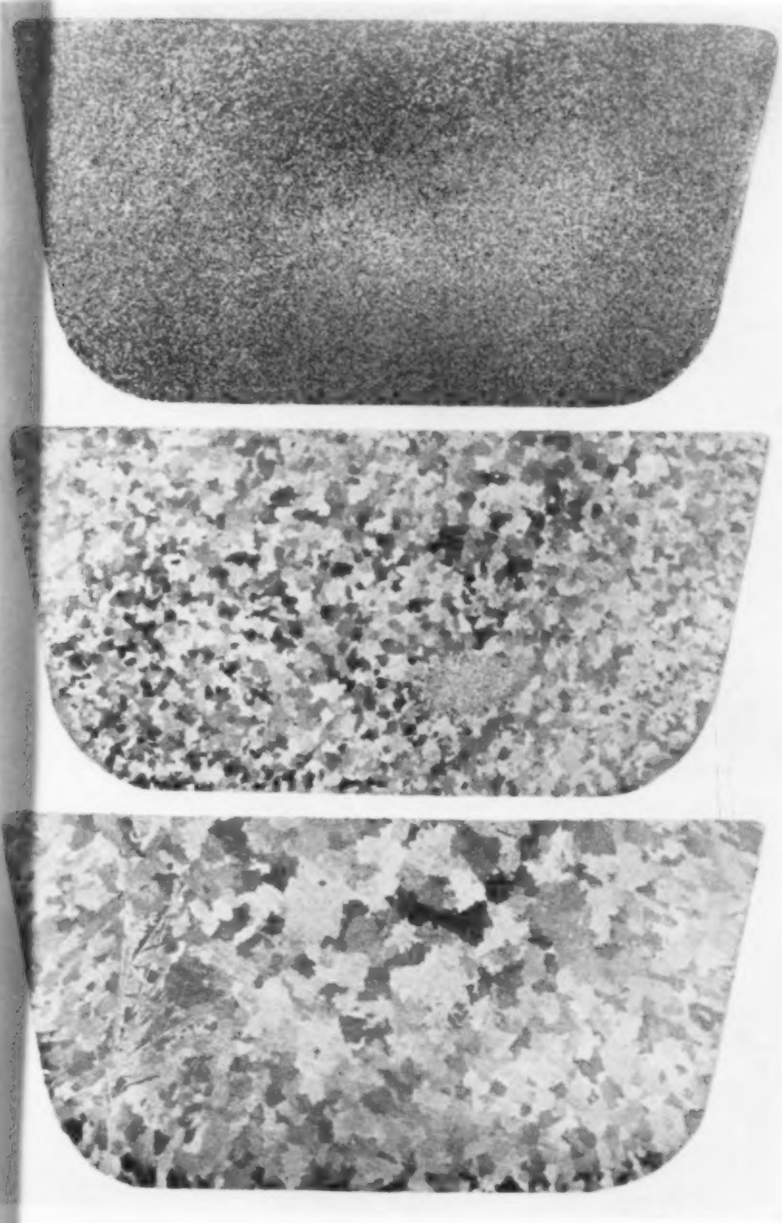
Effect of Titanium on 8% Copper-Aluminum Alloy

Property	Addition, % by Weight			
	None	3% Webbite	1.35% $TiCl_4$	1.5% Webbite +0.77% $TiCl_4$
% Titanium added	0	0.216	0.344	0.303
Titanium content of product	0.012	0.182	0.039	0.140
Yield point, psi.	12,560	14,130	13,875	14,580
Tensile strength, psi.	19,200	21,630	22,160	25,150
% Elongation in 2 in.	2.25	2.8	2.6	3.0
Grains per sq.mm.	2.1	1.56	4.9	8.2

As an example of actual results obtained take the table above, quoted from the research records of the Titanium Alloy Mfg. Co. These data refer to a high grade 8% copper-aluminum alloy, cast at 1300 to 1340° F. in the form of tensile test bars, ½ in. diameter and 2 in. length between shoulders, and tested without machining. The yield point was taken as the stress producing an elongation of 0.5% under load. Titanium additions were made to the melts in two forms, one as an alloy known as "TAM Webbite" containing about 7% titanium and balance aluminum, and the other as the liquid titanium tetrachloride, containing about 25% titanium.

Results in the table should be considered more as a progress report than as the final word on this subject, as it has not always been found that titanium tetrachloride is necessary for the best results. Generally the alloy addition, rather than the chloride, gives the finest grain size, and often the alloy addition alone is sufficient to raise the tensile strength from about 17,000 to over 22,000 psi. Titanium additions to aluminum alloys will not, however, correct the weakening effect of excessive over-heating, or pouring too hot, even though the grain size is refined; and too large an addition, or over 0.4% titanium, has not been found necessary or advisable.

The author wishes to record his indebtedness to the following friends who have helped him in securing the data for this article: Otis Elevator Co. and T. H. Burke, metallurgist, of Buffalo, N. Y., for the manufacture of the chromium-molybdenum-titanium steel castings; Worthington Pump and Machinery Corp. and Messrs. Reynolds and Starkweather, metallurgists, of Buffalo, for data on titanium alloy cast iron; Frontier Bronze Corp. and J. W. Boeck, metallurgist, of Niagara Falls, N. Y., for the manufacture of copper and aluminum alloy castings; R. E. Bannon for testing and micrographs.



Etched Sections of Ingots of an Aluminum Alloy Containing 6% Copper and 1.2% Silicon, Cast at the Same Temperature, to Show Effect of Titanium on Grain Size. The coarse grained ingot contained 0.015% titanium, the intermediate ingot 0.114%, and the fine grained ingot 0.147% titanium. Sections were etched with HF and HCl in water, and magnified two diameters

CORRESPONDENCE

and notes from abroad

Coreless Induction Furnaces Operating on 60 Cycles

SCHWEINFURT, GERMANY — A new type of furnace, constructed by W. Rohn and W. Hessenbruch of the Heraeus Vacuum Melting Co. of Hanau, has aroused a great deal of interest among German metallurgists.

Coreless induction furnaces (or high frequency furnaces as they are better known) are characterized by a cylindrical crucible of refractory surrounded by a helical conductor. The passage of current induces a swirling motion in the molten metal which raises the center, so the surface of the melt is convex. This shape is responsible for certain operating difficulties mentioned below. The new coreless induction furnaces for alternating current (not using high normal frequency but taking current of the number of cycles carried by the transmission lines) have, on the other hand, a flat dish-shaped hearth on which the molten metal swirls in such a way that the center of the bath is about 4 in. lower than the edge.

A considerable improvement over the conventional high frequency induction furnace is obtained by the following (in the view of Messrs. Rohn and Hessenbruch):

1. Independent operation without the use of special high frequency generators and high frequency condensers. It would be desirable to operate directly from the line transformers without a rotary converter, and if possible without Scott connections.

2. A larger bath surface with less depth of bath. A ladle-shaped hearth, similar to the electric arc furnace, would be desirable.

3. Better durability of the lining, especially a basic lining, and elimination of wear or washing at the slag line.

4. Substantially increased speed of reaction by heating the slag to a high temperature. This also permits the use of a minimum amount of slag.

Conductor Coils, Made of Copper Bars, and Their Location in a Six-Pole Furnace

These four requirements were filled by the $1\frac{3}{4}$-ton furnace tested by the Heraeus Co. which operated at 37 cycles. It is clear that the frequency met in large transmission systems would be 50 or 60 cycles, and that a steel furnace on production should hold 4 or 5 tons. Nevertheless, the

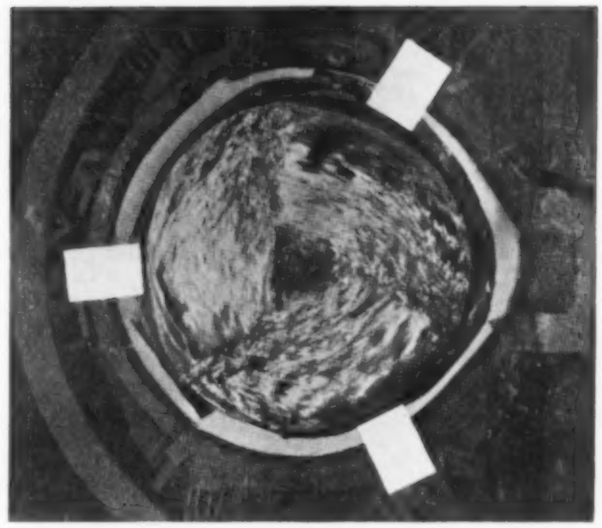
difficulties will be less in such a furnace than the small one actually operated.

This furnace sets inside a ring-shaped yoke made of laminated transformer sheet. Attached to this yoke is the tilting apparatus; inside project three radial polar axes, hemispherical at their ends to correspond to the shape of the bath. Around these polar axes are mounted three copper-covered flat coils in the form of spherical triangles (as shown at left in the half-tone of a similar 6-pole furnace).

Thin-walled copper tubes for cooling water are brazed on the edges of these conductors next the bath. The ends of the poles are likewise cooled by a criss-cross system of cooling tubes. The inside of the coil system (or the outside of the refractory lining) thus consists of a closely packed arrangement of cooling tubes, and the lining of the furnace rests on them. Should the fluid metal penetrate through cracks in the sintered lining, it will be rapidly chilled before damaging the conductors.

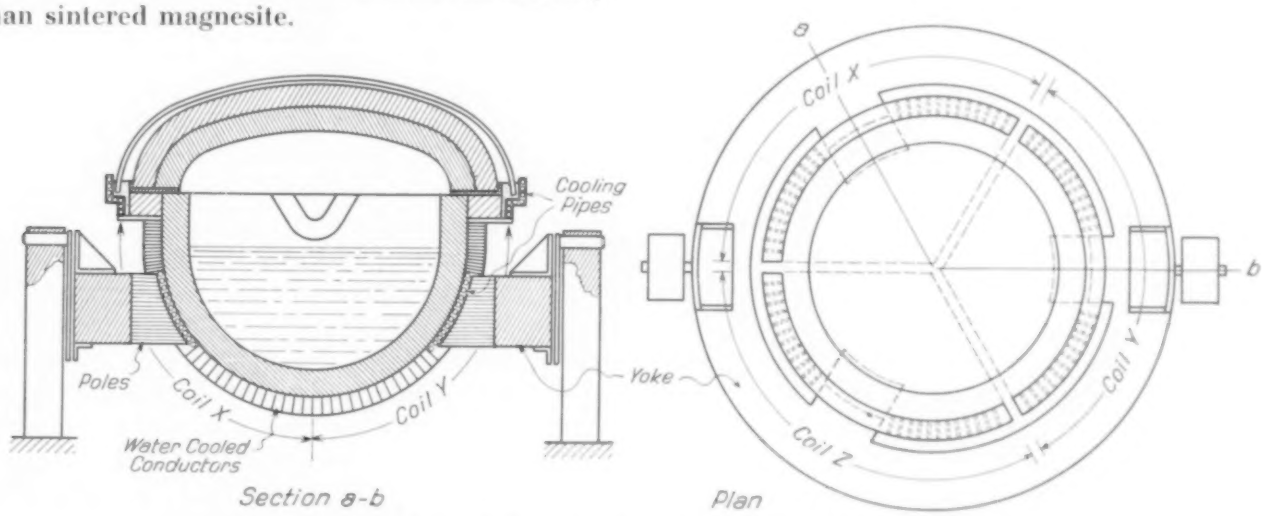
The granular lining material (sintered magnesite with 1½% ground glass) is packed between the coils and a heavy cast steel templet, properly placed. Current is turned on for a short time; the templet gets hot enough to sinter the lining. Next, a wash charge is placed in the templet, the spherical roof placed and the furnace operated in the normal way. Ordinarily the furnace would be used for refining molten metal, as it is not well adapted to melting scrap unless large slabs are carefully placed in front of the pole pieces.

For metals more refractory than iron the lining may be made of electrically melted magnesia, which has withstood temperatures up to 3600° F. It also has 30% lower heat conductivity than sintered magnesite.



Photograph of Swirling Surface of Molten Steel. White rectangles denote position of the poles on the supporting yoke

The view above shows how the bath swirls about the poles. It also revolves slowly around a perpendicular axis, and in this way the surface of the bath is depressed in the center. Surplus slag is therefore retained in a central pool rather than thrown to the edges, as in the ordinary high frequency furnace, and protects the lining. Strong vertical currents in opposite directions exist in three regions of the bath, and this entraps and emulsifies a considerable quantity of slag very effectively. The metallurgical effect of the slag-metal reaction is quite significant, when one considers that 200 lb. of slag can be so completely mixed with 2 tons of metal in the bath that the surface of the metal appears to be free of slag. It is possible to reduce carbon from 1% to 0.04% in less than 40 min. and sulphur from 0.060 to 0.020%.



Diagrammatic Plan and Cross Section of Three-Pole Induction Furnace (Coreless) to Operate at Line Frequency and in Controlled Atmosphere

If refining is to be finished at a higher temperature, the phosphorus slag is drawn off. By the addition of lime and bauxite or fluorspar a new, sufficiently fluid slag is obtained and the energy input is reduced to 1/3 to 1/5 the maximum power of the furnace. The strong motion in the bath then stops, and the slag thus forms a cover and the metal is purged of oxide inclusions. The reaction of the new sulphur slag is still so strong that a melt with 0.040% S can be reduced to 0.010% within 5 or 10 min.

At the Heraeus plant the furnace was used for the manufacture of the purest iron, and for decarburization of 18-8 chromium-nickel steel to less than 0.02% C. It is announced that the Krupp Company at Essen and the Deutschen Edelstahlwerke at Krefeld are to install induction furnaces of this type, using alternating current of normal transmission line frequency.

HANS DIERGARTEN

Grain Size vs. Surface Hardness; a Question of Mass

KEARNEY, N. J. — In an article on "Grain Size in Steel," published in METAL PROGRESS in August, the author R. L. Wilson states that the coarse grained steels harden to a greater intensity of surface hardness than fine grained steels of like chemical composition. This is somewhat at variance with the experience gained by us at the Research Laboratory of the U. S. Steel Corporation, during the course of many hundreds of hardenability investigations on a wide variety of carbon and low-alloy steels. We have encountered some exceptions, of course, but the general rule certainly has seemed to be that the coarse grained, deep hardening condition in any given steel resulted in a lower intensity of surface hardness than the fine grained, shallow hardening condition.

Examples of this behavior have been given in some of E. C. Bain's recent publications, such as: Fig. 2 and 10 of the 1932 Campbell Memorial Lecture (*Transactions*, Vol. 20); Fig. 4 in the discussion of M. A. Grossmann's paper in *Transactions* for December, 1933; and Fig. 6 and 8, in the paper entitled "Some Characteristics Common to Carbon and Alloy Steels" read before the American Iron and Steel Institute at New York in May, 1934.

We have attributed this lower intensity of surface hardness in the deeper hardening steels to a larger proportion of retained austenite in the surface layers of these steels, although for the present discussion, the interpretation is probably of less importance than the correct observation and establishment of the facts about the phenomenon.

The above is but a specific criticism. Mr. Wilson is to be congratulated on his timely article. It constitutes an excellent review of the present status of our knowledge of an important phase of steel metallurgy and, in addition, contains several new items of information which have not been generally recognized up to this time. The article should be welcomed by all those concerned with the effects of grain size on properties — a subject which has been agitating metallurgists for the past few years.

E. S. DAVENPORT

MR. WILSON REPLIES

CANTON, OHIO — We can appreciate Mr. Davenport's interest in questioning whether coarse grained steels harden to greater intensity of surface hardness than fine grained steels of like chemical composition. Generalizations of this kind are usually fraught with the danger that they may be disproven in detail, depending upon the viewpoint taken.

In our discussion of the concept of grain size in steel we have attempted to accommodate the scientific facts to the selection of steels as materials of construction for engineering purposes. This may allow some license in expressing a preference for what may be called the rule and the exception.

The results of Mr. Davenport's researches and the references mentioned lend support to his contention that the fine grained shallow-hardening steels really develop the greater surface hardness on quenching. On the contrary, it seems equally reasonable to say that the coarse grained steels will develop higher surface hardness than the fine grained steels *unless* the quenching has been so drastic as to favor the retention of austenite in the structure.

For example, in Fig. 8 in Bain's paper last mentioned, the hardenability of the same steel is shown for austenite grain sizes ranging No. 2 to No. 5 on the A.S.T.M. standard chart, all the specimens being within the class of coarse grained steels by definition. Specimen E of finest grain size has the lowest surface hardness, and it appears that the hardness would increase gradually with coarser grain size, were it not for the counter effect of austenite retained due to the

change in critical cooling velocity induced by the coarser grain size.

In most studies on the hardening characteristics of steels, pieces of small size have been quenched drastically to obtain the specimens used for making hardness surveys. The practice is convenient for comparing the "hardening power" of steels under ideal conditions, and in particular affords a means of drawing fine distinctions in evaluating the hardenability of the shallow hardening steels. The relative hardenability of steels as so determined by quenching small pieces, can be assumed to apply in the case of larger pieces as well, but from the practical standpoint we are concerned mainly with the change in the shape of the hardness distribution curve across the section when pieces of larger section and greater mass are quenched normally in oil or water.

The principal factors governing the rate of quenching in pieces of large size operate against the retention of austenite in the surface layers of the steel. A large mass of steel, acting simply as a heat receptacle, reduces the effective quenching capacity of the coolant. Besides, the heavier scale on the surface of the steel, which is scarcely avoidable in the longer heating time before quenching, also retards the speed of quenching.

Under these conditions (which are quite common in the application of steels) we have found that the coarse grained steels harden more deeply and to higher surface hardness than the fine grained steels.

R. L. Wilson

Shape of Impact Test Piece

TURIN, Italy — One of my preceding letters, published in December of 1932, noted the introduction of the impact test into the Italian State Railways' standard specifications for ordinary untreated carbon steels. Notwithstanding extensive comparative researches carried out prior to its adoption, to determine the type of test bar best qualified to give reliable and comparable results for untreated carbon steels, it cannot be said that the compromise adopted by my countrymen was satisfactory to all parties at issue. How many more uncertainties, therefore, still remain concerning the choice of a given type of notch for an international standard to measure toughness of a metal!

For the purpose of our railway specifications the standard Mesnager bar (10x10x55 mm. and notch 2 mm. deep with bottom rounded to 1 mm. radius) was adopted. On the other hand, the German metallurgical and testing societies believe that, in a 10-mm. bar, the same notch deepened to 3 mm. is much more desirable. The French standard (barreau U.F.) again differs by using the same type of notch cut 5 mm. deep. The matter is further complicated by the occasional use of a square-bottomed saw cut, 1 mm. deep in a 10x8-mm. test piece (Fremont type) and the indiscriminate use, in England and America, of a keyhole notch in a Charpy impact machine or the V notch in round or square specimens in an Izod machine.

Some new data are now available as a basis for the discussion of this problem, at least as regards the Mesnager notch and the German notch 1 mm. deeper. These data are based on more than 100,000 impact tests on a few well-defined typical carbon steels, and have been published by M. Steccanella of the Italian State Railways in *Metallurgia Italiana*.

The carbon contents of the six principal steels tested varied between 0.21 and 0.51%. They were rolled under the same general mill conditions, and comparisons were made between the impact resistances of these steels after reheating in three different time-temperature cycles. The results may therefore be accepted as conclusive for medium carbon steels in serviceable condition.

The first general conclusion derived by Mr. Steccanella from his experiments is that the test bars with notch 2 mm. deep give more uniform results for a given steel (especially when in the untreated or as-rolled condition) than the bar with the 3-mm. notch.

In the second place, the tests made on bars with notch 2 mm. deep show greater differences, steel to steel, either as rolled or normally reheated.

It would appear, then, that the test bar with 2-mm. notch better satisfies the two essential conditions for reliable tests — (*a*) uniform results for uniform materials and (*b*) different results for different materials.

When these steels are reheated for exceptionally long times at rather high temperatures, test pieces with the 3-mm. notch give a sharper differentiation of results, but these conditions do not correspond to the average conditions of the practical problem now under consideration, nor to the actual service of the steels.

It is proper to point out that the advantages as stated above are not measured in large nu-

merical values, but — if confirmed by other experiments — they would be sufficient to reject the claimed superiority of the bar with a 3-mm. notch (at least for the carbon steels studied by Mr. Steccanella).

No extensive comparative experiments have yet been published concerning the test bar with notch 5 mm. deep, proposed by the French delegation at the Düsseldorf meeting of the International Committee for Steel Standardization. Such results will probably be submitted to the next Congress of the International Association for Testing Materials.

In any case the results of Steccanella's experiments show clearly that the various technical details connected with the impact test should be submitted to very extensive researches before such a test can be acceptable as an international standard.

FEDERICO GIOLITTI

Standard Carbon Tool Steels (U.S.S.R.)

Designation	Carbon	Manganese	Silicon Max.	Sulphur Max.	Phosphorus Max.
High Grade (Crucible or Electric)					
Y7A	0.60 to 0.74	0.25 to 0.35	0.30	0.020	0.030
Y8A	0.75 to 0.85	0.25 to 0.35	0.30	0.020	0.030
Y9A	0.86 to 0.94	0.20 to 0.30	0.30	0.020	0.030
Y10A	0.95 to 1.09	0.15 to 0.25	0.30	0.020	0.030
Y12A	1.10 to 1.25	0.15 to 0.25	0.30	0.020	0.030
Y13A	1.26 to 1.40	0.25 to 0.35	0.30	0.020	0.030
Ordinary Grade (Open-Hearth Permissible)					
Y7	0.60 to 0.74	0.40 max.	0.35	0.030	0.040
Y8	0.75 to 0.85	0.40 max.	0.35	0.030	0.040
Y9	0.86 to 0.94	0.35 max.	0.35	0.030	0.040
Y10	0.95 to 1.09	0.30 max.	0.35	0.030	0.040
Y12	1.10 to 1.25	0.30 max.	0.35	0.030	0.040
Y13	1.26 to 1.40	0.40 max.	0.35	0.030	0.040

Standard High Speed Tool Steels (U.S.S.R.)

Composition	Designation				
	PK5	PF2 (a)	PF1	P	PO
Carbon	0.65 to 0.77	0.71 to 0.77	0.68 to 0.80	0.66 to 0.68	0.60 to 0.75
Tungsten	17.0 to 18.5	11.8 to 12.8	17.5 to 19.0	17.0 to 18.5	15.0 to 17.3
Vanadium	1.0 to 1.4	2.3 to 2.6	1.0 to 1.4	0.5 to 0.8	0.2 to 0.6 (b)
Cobalt	4.5 to 5.5				
Molybdenum	0.3 to 0.6		0.3 (c)	0.3 (c)	
Chromium	3.6 to 4.5	4.1 to 4.6	3.8 to 4.6	3.8 to 4.6	3.3 to 4.3
Manganese, max.	0.40	0.40	0.40	0.40	0.40
Silicon, max.	0.40	0.40	0.40	0.40	0.40
Nickel, max.	0.20	0.20	0.20	0.20	0.20
Sulphur, max.	0.030	0.020	0.030	0.030	0.030
Phosphorus, max.	0.030	0.030	0.030	0.030	0.030

Note: (a) Preferred grade (b) Optional (c) According to order

Standardized Tool Steels

GROSNY, U.S.S.R. — Standardization of tool steels used in the Soviet Union has been necessary to simplify their manufacture, reduce the cost, and at the same time facilitate the choice of tool steels for special use by the purchaser.

Conditions now existing here, resulting from the development of our national economy according to plan, and the centralization of manufacture of tool steels at a few steel works belonging to the state, favor such a plan of standardization. Therefore the Soviet metallurgists have more opportunity to simplify their practices than metallurgists abroad, where standardization of tool steels is complicated by competition between individual firms.

The difference between the properties of some tool steels to be used for the same purpose manufactured by various foreign firms and sold at the market under different names is often very slight, and in most cases has no significance as to the serviceability of the tool and its cutting properties, but is often maintained for the sake of trade competition.

To point out the difference in conditions in respect to the number of tool steel grades available in the Soviet Union and abroad, it can be said that there are now about 200 grades of carbon tool steel on sale in the U.S.A. and about 100 in Germany. The new Soviet standard specification No. 4956, adopted in March 1933, gives only 12 grades of tool steel, six of which are classed as "high grade carbon steels" and six as "ordinary carbon tool steels."

According to this standard, high grade steels must be manufactured in crucible or electric furnaces only, while the ordinary grade may be manufactured in open-hearth furnaces, if the raw materials used are pure. Chemical specifications are given in the accompanying table.

There are about 100 grades of high speed steels and 300 grades for alloy tool steels on sale in the United States and about 60 and 200 respectively in Germany, whereas the new Soviet standard specification

No. 4957, also adopted last March, permits only five grades for high speed, and specification No. 4958 gives 21 grades for alloy tool steels. Analyses of the high speed steels are listed in the table.

It will be noted that the preferred analysis is low in tungsten and high in vanadium.

The chief principles taken into consideration when setting up these standards by the Committee on Standardization are:

1. Adoption of as few grades of tool steel as possible, but of such nature as would fully satisfy the purchaser's needs.

2. The available supply of raw material for alloying elements. We possess large supplies for the production of ferromanganese, ferrosilicon, ferrochrome, and ferrovanadium. On the other hand, we are short on ores to produce ferrotungsten and ferromolybdenum. For this reason PF2 has been adopted as a preferred grade, even though this analysis formerly was not used.

B. M. Suslov

Founding Properties of Alloys

PARIS, France — Foundry science consists, first of all, in obtaining sound pieces having the desired dimensions and shape. Only when this is done can one improve the mechanical properties. It is, in fact, quite uninteresting to search for an alloy having a high value of some specific mechanical property, when the foundryman cannot obtain sound and well-made pieces of the indicated composition.

This essential condition depends upon a certain number of phenomena and complex properties that have been called foundry characteristics, or founding properties, such as castability, propensity to pipe, total contraction, liability to cracks and blisters. These phenomena and properties depend on a great number of elementary factors (which have been enumerated by the present writer at a recent meeting of l'Association Technique de Fonderie) and this is the reason why it is almost impossible to analyze separately these foundry characteristics. They must be studied and evaluated by direct experience.

Unfortunately for the foundry industry, they have not yet been much studied. Researches have generally been directed toward the specific properties of alloys — mechanical, physical, or chemical — and this explains the rather backward state of the art and science.

Yet the problems are by no means impossible to solve. As the mechanical properties are measured and controlled by means of certain test pieces, so the foundry characteristics or foundry properties may be measured and controlled by means of "foundry test pieces."

Thus, it will be possible to get a good idea of the castability of metal with a spiral, flat, or horizontal test piece, fed at one end and the length of which will be noted. Propensity to pipe and blisters may be estimated from small ingots whose surface can be studied, the apparent density measured, and various cross-sections examined either as cut or after various etchings. Aptitude to cracks and to internal stresses shows up on pieces shaped like a rectangular frame with small sides or arms fixed to a thicker, less yielding part. Cracks may be observed at the re-entrant angles. Internal stresses may be figured from the change in size and shape as portions of the outer frame are progressively removed by machining.

All the work connected with molding and feeding these test pieces must be done so as to promote the following conditions:

(1) Sufficient sensitivity. This is done by magnifying the defects that must be exposed to view, so that the alloys may be differentiated one from another, and the influence of various foundry conditions clearly indicated.

(2) Indispensable accuracy and uniformity — that is, the reproduction of the same result when the work is repeated practically under the same foundry conditions.

A little thought shows that the first condition mentioned above requires the test pieces to be produced in a way that is exactly contrary to normal good foundry practice (which naturally seeks to avoid or to minimize the foundry defects). Thus it is that the test piece for castability is one that does not fill the mold — that is, the investigator voluntarily obtains a badly made piece of metal.

Pipe will also be exaggerated by the suppression of any feeding risers or sink heads and by the use of a metallic mold to conduct the heat rapidly away from the surface.

For showing cracks a rigid shape must be chosen, with sharp re-entrant angles and unequal in thickness, a form every designer likes to avoid.

When casting test pieces to show blisters, the metal must emit gases during solidification; more particularly, the solidification must be carried out under a reduced pressure in a partial vacuum.

Such a research which goes to great pains to obtain defects is very useful, contrary to what might be thought. In fact, when one is able to *cause*, voluntarily, a defect of a determined size or kind, one is also able to *avoid* it, merely by working in the opposite direction.

The introduction and the use of such accurate and reproducible foundry test pieces will transform that technique and will bring to the foundry the same improvement that the use of test pieces for mechanical tests and chemical control brought to metallurgy.

ALBERT PORTEVIN

Refining Jeweler's Sweepings with Arsenic

GLASGOW, SCOTLAND — What with the growing use of platinum alloys in industry, rare metal scrap and goldsmith's sweepings are much more complex materials than a generation ago, since they contain recoverable amounts of rare metals of the platinum group. It is in their recovery that arsenic plays an important part. Progress in the art of recovering and separating such precious metals is slow, not because they are complex to handle, but because of the secrecy which is observed, which prevents antiquated methods being revealed, and improved modern systems introduced.

Practically nothing has been published on this subject, and in view of the article in METAL PROGRESS some time since on "The March of Platinum in Industry" by E. M. Wise, readers may be interested in some fragmentary data culled from my own experience.

Although the process was originally worked out by D'Hennin some 50 years ago, it was not patented, and use was made of the system privately by platinum refiners. The principle involved is that irrespective of the quality or composition of the precious metal wastes, a proper amount of arsenic can be depended upon to prevent the heavy metals sinking into the hearths when the materials are being melted with lead. Prior to its introduction, and apparently with some of the older-fashioned smelting firms today, the gold and platinum are refined without this important addition, whereby more or less of the heaviest metals, namely, iridium and osmium, are absorbed in the brickwork of the furnace bottoms, there to remain until the owner is moved to dismantle the brickwork and smelt it to recover its values.

In practically all instances the rare metal sweepings or fines are melted with a large excess of lead. Arsenic then causes the iridium, ruthenium, rhodium, and osmium to float to the surface in a scum that can be removed, whilst the bulk of the molten lead, containing most of the platinum and palladium, is transferred to the "test," a flat pan lined with bone ash where the lead is oxidized and either volatilizes or is absorbed into the bottom during cupellation. A comparatively complete separation is effected.

There are several methods of introducing the arsenic, although progress toward the best and most economical is severely handicapped by secrecy. All lead used in the process would ordinarily be of the arsenical variety containing a few per cent of arsenic, but the skimmings often have the precious constituents imperfectly alloyed, whereupon it is necessary to introduce additional arsenic. To do this, almost any class of arsenical waste will suffice.

Sludges from nickel works may be procured, which consist of iron arsenate. Calcium arsenate is also procured as a waste material, whilst crude sodium arsenate from dyers' waste was the original material employed. These arsenates are fluxed with siliceous additions, and if necessary a slight amount of sulphur is also added to assist the separation. Fine coal is mixed with the mass prior to charging, to insure that all arsenic is converted to the metallic condition, suitable for alloying.

It is commonly asserted in most text-books that arsenic sulphide on heating sublimes unchanged. The writer found that this is scarcely accurate, and that if suitably applied could be used to form a matte and a white metal which gave a good separation of the platinum metals. In these experiments the arsenic sulphide employed was that waste material procured from the earlier sulphuric acid process in which arsenic was separated by means of H_2S.

The products from the first smelting are lead, white metal, matte, and slag. The white metal is concentrated by sulphurizing repeatedly until a rich speiss is formed; the former may contain anything up to 90 oz. of iridium per ton, togther with from 4 to 8 oz. of rhodium and ruthenium, but the concentrated speiss contains about ten times these quantities.

What surplus arsenic is present passes to the fume-condensers, from which arsenical lead is recovered and reused in the process. Hence the operations are carried out with great simplicity and economy.

C. C. DOWNIE

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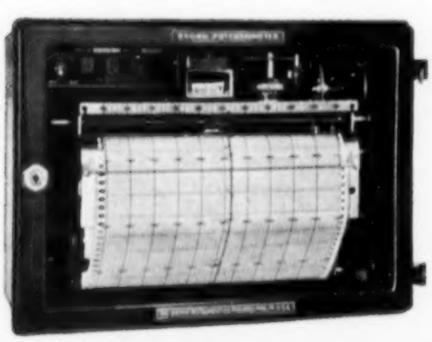

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"Stroborama" Stroboscope, Engineer, Sept. 21, p. 293 . . . . Skoda-Sawin Wear Testing Machine, Engineer, Dec. 7, p. 565 . . . . Radiographic Examination of Rivets, V. E. Pullin, Engineer, Nov. 2, p. 429 . . . . Quality of Steel—Magnetic Tests, T. F. Wall, Engineer, Dec. 7, p. 564.

Metallographic Work at Low Temperatures, O. A. Knight, Metals & Alloys, Nov., p. 256 . . . . Metallography of Ferrite in Malleable Cast Iron, H. A. Schwartz, American Foundrymen's Association, October Meeting . . . . Photomicrography With Utra Violet Radiation, A. J. Allen, Journal Franklin Institute, Dec., p. 701 . . . . Veining of Ferrite, L. Northcott, Metallurgist, Oct. 2, p. 163.

Permissible Stress Range for Small Helical Springs, F. P. Zimmerli, University of Michigan Engineering Research Bulletin No. 26.

Influence of Notches on Fatigue of Metals, D. J. McAdam, Jr., Bureau of Standards Journal of Research, Oct., p. 527.

Powder Metallurgy of Ferrous Materials, Charles Hardy, Steel, Nov. 19, p. 52 . . . . Effects of Hydrogen in Steel, Metallurgist, Oct. 26, p. 171 . . . . Prediction of Equilibrium Conditions in Alloy Systems, Metallurgist, Oct. 26, p. 174.

HELPFUL LITERATURE

Free for the Asking

Deoscillator

How you can wipe out bothersome temperature lags at small expense is told by Foxboro Co. in a bulletin describing the Deoscillator, an auxiliary control unit which, when operated with the regular pyrometers, gives an anticipating effect to the control action. Bulletin Jx-21.

Pre-Heating Furnace

General heat treating operations up to 1900° F., pre-heating of high speed steel, annealing and firing of glass are some of the applications listed in American Electric Furnace Co.'s folder on their new model B-20 furnace. Bulletin Jx-2.

Dark Room Layout

A novel card 9½x13 in. containing suggested arrangements for a photomicrographic dark room has been designed by Bausch & Lomb. Costs for installation are estimated, and on the reverse side are printed rules for using the dark room. Bulletin Jx-35.

Radium Radiography

Advantages of portability, ease of application and manipulation in examination of castings, forgings, molds, weldings, and assemblies are attributed to radium for industrial radiography. Details are given in a booklet issued by Radon Co. Bulletin Jx-56.

Blast Cleaning

A centrifugal machine which cleans castings without the use of compressed air is the subject of Pangborn Corporation's new folder. How and why 1800 lb. of castings can be cleaned in 8 min. at low cost is told. Bulletin Jx-68.

Electric Furnaces

A wealth of information on controlled atmosphere electric furnaces is contained in General Electric Co.'s booklet by that name. Detailed data are given on electric brazing in particular. Bulletin Jx-60.

Multiple Tables

Ten convenient and simple tables in this booklet by Timken Steel & Tube enable the steel user to tell at a glance either how long his stock must be to furnish a definite number of multiples, or how many multiples can be cut from a given length of stock. Bulletin Dc-71.

Fast-Cutting Steel

Bliss & Laughlin, Inc., offer an interesting technical folder on Ultra-Cut Steel, giving performance records of this high-speed screw stock on automatic screw machines. Physical data and microstructures are presented. Bulletin Ob-42.

Hard Carbide

An extremely interesting little booklet describes "the hardest material ever produced by man for commercial use." This is boron carbide, and its manufacture, properties, and uses as an abrasive and as a wear resisting material are told by Norton Co. Bulletin Dc-88.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Everdur

Properties, applications, and forms available of this copper-silicon-manganese alloy are described by American Brass Co. High strength and corrosion resistance, ductility, weldability, workability, and moderate price are some of the advantages featured. Bulletin Dc-89.

X-Rayed Alloy Castings

Electro Alloys Co. describes their X-Ray inspection of Thermalloy heat resisting castings for high temperature work. Considerable data on the use of X-Ray tubes and "radon" capsules to check foundry practice are presented. Bulletin Oc-32.

Thermit Welding

Metal & Thermit Corp. offers a new booklet showing all the possibilities of Thermit welding, explaining the action, and telling in detail how representative Thermit welds can best be made. Well illustrated and clearly written. Bulletin Ar-64.

High Strength Steel

Cromansil steel, a development of Electro Metallurgical Co., has high strength and good ductility "as rolled" and is thus fine for structural applications where its great strength saves much dead weight. Bulletin Je-16.

Aluminum Alloys

Working facts on aluminum — the properties and heat treatment of both cast and wrought alloys — are briefed for the manufacturer and designer in a booklet by Aluminum Co. of America. An appendix gives tables of physical properties, forms and sizes available. Bulletin Dc-54.

Air for Furnaces

Users of gas or oil-fired furnaces know the necessity for a dependable source of large volumes of air at low pressures. A generously illustrated folder of Spencer Turbine Co. shows why their Turbo-Compressors give unfailing, economical air service. Bulletin Mr-70.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Molybdenum in 1934

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

Atmosphere Furnaces

An interesting folder of Surface Combustion Corp. gives performance data on their atmosphere furnaces in actual production bright annealing of ferrous and non-ferrous metals and carburizing, nitriding, forging and hardening without scale. Bulletin De-51.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Nv-38.

Sheet Iron Primer

The fifth edition of Republic's handsome 64-page booklet which tells the story of modern sheet iron in simple, non-technical language is now available. Gage tables and an interesting glossary of metallurgical terms are included. Bulletin Dc-8.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. Bulletin S-27.

Multiple Point Records

A circular describing Leeds & Northrup's Micromax Multi-Color 6-point Recorder gives a reproduction of an actual chart in six colors showing how each numeral is printed in a contrasting color, thus avoiding errors and saving time. Bulletin Dc-46-A.

Nickel Cast Iron's Uses

The role of nickel and nickel-chromium cast iron parts in such applications as fabricating sheet metal, pressing and forging is interestingly explained in a new pamphlet of International Nickel Co. Bulletin Ag-45.

The Lindberg Control

The Lindberg Control announced a few months ago for electric furnaces is now available for fuel fired furnaces. Controlling the input of fuel fired furnaces eliminates the lag caused by the protecting tube around the thermocouple and results in straight line temperature control. Nv-66.

Hardness Testing

Men interested in hardness testing may find it worth while to read the recent catalog of Wilson Mechanical Instrument Co. which describes the latest design of Rockwell hardness testers and auxiliary work supports. Bulletin Sp-22.

Carbonol Process

The Carbonol process of carburizing is described in detail in a folder of Hevi Duty Electric Co. Results are said to be quicker, cleaner and better cases at very low cost. Bulletin Jy-44.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Hardening Furnaces

The C. I. Hayes Certain Curtain electric furnace for the range 1200 to 1850° F. is described in this bulletin. Its applications to hardening of carbon, stainless, and alloy tool steels and to preheating high speed steel are discussed. Nv-15.

Properties of Stainless

Carpenter Steel Co. offers (to manufacturers in U. S. A. only) a handy pocket size slide chart which gives at a glance a summary of technical data on all Carpenter stainless steels. Bulletin Se-12.

Cold Drawn Shapes

Many applications of cold drawn squares and flats are enumerated by Union Drawn Steel Co. in this folder. Sizes, grades of finish, and compositions available are listed. Nv-83.

Induction Furnaces

A publication of Ajax Electrothermic Corp. tells of the development, operating principles, applications, and advantages of commercial Ajax-Northrup coreless induction furnaces energized by motor generator sets. Also information regarding standard sizes of motor generator sets and furnaces. Bulletin Jr-41.

Cyanides and Salts

R & H Chemicals Department of E. I. du Pont de Nemours Co. has a new 28-page manual on the procedure for case hardening, reheating, nitriding, and mottling of steels with cyanides, and on coloring, tempering, and drawing with salts. Nv-29.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Reports on Firebrick

Babcock and Wilcox Company offer a very complete set of Service Reports on Insulating Firebrick. These reports contain valuable data on adaptability of refractories and savings possible. Bulletin Ob-75.

Welding Rods

Linde Air Products Co. has published an attractive book which describes in clear, non-technical language the properties, characteristics, and uses of every type of Oxweld welding rod. A fund of reliable general information on welding rods is an important feature of the book. Bulletin Jr-63.

Metallograph

A new 36-page booklet of E. Leitz, Inc., contains all information on the Leitz large Micro-Metallograph, MM 1. Excellent photomicrographs are reproduced to show its capacity. Special attention is given to the darkfield illumination feature. Bulletin Se-47.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Manual of Pyrometry

Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

Localized Heat Treating

American Gas Furnace Co. offers information on production machines for localized hardening, tempering or annealing of tools, saws, springs, screws and machine parts of all kinds, using gas as fuel. Bulletin Ag-11.

Metal Progress
7016 Euclid Ave., Cleveland

Please have sent to me without charge or obligation the following Literature described in the Jan. issue. (Please order by number only.)

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— that of high conductivity, high strength copper cable. But outside of this, my guess is that the demand for age hardening non-ferrous alloys in the near future is likely to be intensive rather than extensive, varied in character rather than simple, and that the alloys used will be many rather than few. Consequently, their development may be slow in tempo. This development will certainly give the metallurgist plenty of mental exercise and worry, but it may, only slowly, make much money for the producer and the user.

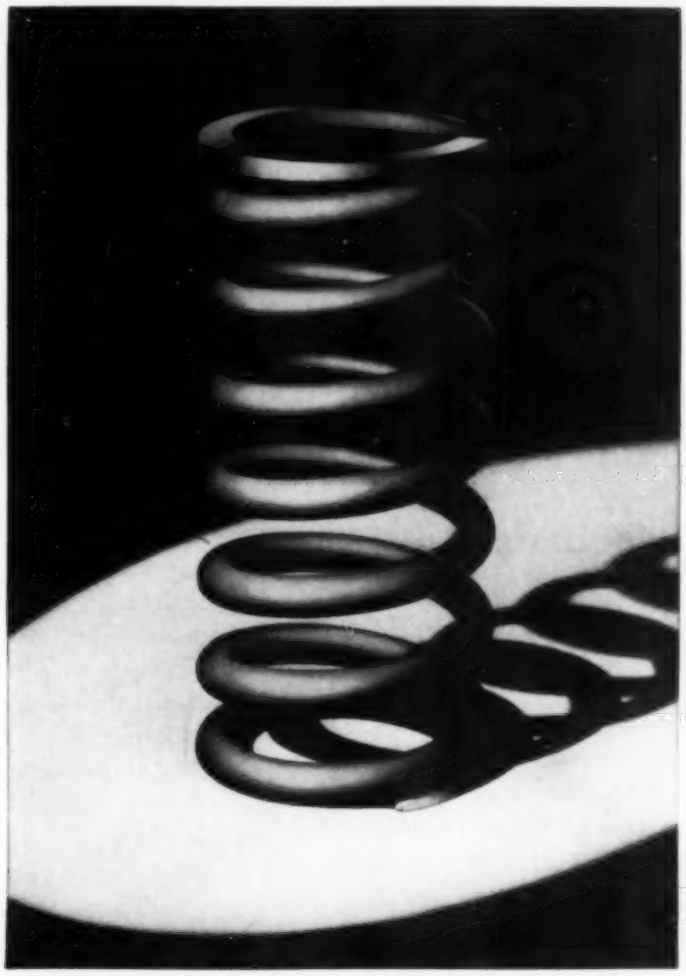
But I have little doubt that even outside of those fields in which a fairly broad demand exists for high strength non-ferrous alloys, age hardening alloys will in their own diverse ways ultimately prove to be of great importance to users of metals. In order for them to "make good" they will have to be flexible and agile of performance, they will have to squeeze into tight places — and into tight specifications. They will have to fit themselves for the increasing number of special needs and requirements of our metal fabricating and manufacturing industries. Fortunately, this is just the sort of situation for which they are, on the whole, admirably adapted.

Changes But One Property

For alloys may be rendered age hardenable by the addition of very small amounts of the hardening agent. Aluminum is hardened, for example, by the addition of about 1.5% of magnesium plus silicon, and lead, with as little as 0.1% of calcium. Indeed, we may accept it as *theoretically* possible, at least, to find some suitable hardening agent, which in modest proportion will harden *any* alloy, no matter what its composition. Now, although such an addition may profoundly affect the mechanical properties of the base alloy, it is not likely to affect very appreciably its chemical and physical properties — particularly if the required or added amount is small. We are thus in position by the age hardening method, again theoretically, to alter the mechanical properties of alloys independently of their other properties. So in the future when we require special alloys for special purposes, I think we shall be apt to turn to age hardening as a convenient and ready answer.

In Selecting A Steel For Coil Springs,

Bear In Mind –



VANCORAM

FERRO-ALLOYS
of vanadium, silicon, chromium, titanium, and silico-manganese, produced by the Vanadium Corporation of America, are used by steel makers in the production of high-quality steels.

The problem in selecting a steel is to choose one that will enable the manufacturer to duplicate the results desired thousands and thousands of times with regularity and a minimum of effort and cost.

Its demonstrated melt to melt uniformity and its conceded freedom from sensitivity make Silicon-Vanadium the ideal analysis for coil springs of many types.

Metallurgists of the Vanadium Corporation, familiar with the difficulties of spring design and manufacture, will be glad to co-operate with you.

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VANADIUM STEELS

for strength, toughness and durability

IRON AND STEEL

stainless has certain advantages over the light metals, such as superior resistance to corrosion, abrasion and nicking; it will also stand more heat without softening.

The weight reduction which is now sought in the transportation industry will be obtained first by a more careful study of design in the cheaper materials — plain carbon and low alloy steels — and secondly by the use of stainless steel and of the light metals in accordance with their peculiar merits.

Future Trends

Perhaps the most marked trend of very recent years and of today might be defined as an intensive study of the application of iron and steel. The problem of the user is to select materials that will fulfill the required functions at the lowest ultimate cost. In the past it has been necessary to concentrate attention largely upon satisfactory performance, and this will, of course, always be an essential part of the problem. There is now available for most purposes, however, a considerable variety of materials which will perform satisfactorily, and attention is being directed more and more to the cost factor. In this effort, it is realized that the true criterion is not the first cost of the raw material, but the final cost of the fully fabricated product.

There is in view no basically new process of steel manufacture, applicable in our principal industrial areas, which offers any substantial economies in the making of steel. There is room for further economies in the operation of present methods, particularly in the direction of bringing these methods under closer control. And there is decidedly an opportunity for substantial reductions in the cost of finished steel products to the ultimate consumer through the intensive study of applications and of fabricating processes which is now taking place.

The extension of the use of steel into new fields has not stopped. The era of tonnage development was in the hands of the very capable practical steel-masters. There has now been added the powerful aid of applied science, and the result can only be a still further increase in the already remarkable utility of iron and steel to mankind.